Psychologic

HOWARD C. W
JOHN B. WATSON, Joh
JAMES R. ANGELL, U
SHEPHERD I. FR
MADISO

HARVA

PSYCH

containing original contribu
July, September, and Novem
480 pages.

PSYCHO

containing critical reviews, n
ature, university notices, and
comprising about 480 pages,
reviews of recent work in

JOURNAL OF E

containing original contribu
monthly, February, April, Ju
bers comprising a volume of

PSYCH

is a compendious bibliograph
logical and cognate topics th
issued annually in May, and
periodicals above, or purcha

ANNUA

Review and Bulletin, $5 (C
Bulletin, $2.75 (Canada,
Journal, $3 (Canada
Review, Bulletin, Journal and
Review, Bulletin and Jo
Review, Bulletin and
Current Numbers: Review,

THE PSYCHO

consist of longer researches o
it is important to publish pro
prices according to their siz
and are gathered into volume
price of $4.00. (Postal Unio

Philosophical Monographs:
Library of Genetic Science

Subscriptions, orders, and bu

PSYCHOLOG

PRIN

Foreign Agents: G. E. Stech
Leipzig (Koenig

EFFECTS OF PRACTICE IN THE DISCRIMINATION AND SINGING OF TONES

Edward Herbert Cameron, Ph.D.
Assistant Professor of Education
Yale University

A study (1) of the effects of practice on singing tones at two different pitch levels near the upper and lower limits of the range of the male voice; and (2) of the relation of these activities to discrimination of tones.

Practice in singing a tone of a certain pitch level resulted in improvement in accuracy of pitch of the tone in the cases of four out of six subjects. This improvement was not present in the singing of tones at a different level from that in which practice had taken place. Practice in singing tones of a certain pitch was followed by improvement in discrimination of tones of the same pitch but no improvement in discrimination took place at the other pitch level. Improvement in the *uniformity* of the practised sung tone was transferred to the other level.

Perhaps in no other sphere is the usual voluntary response to a sensory stimulus more precise and unvarying than in the reproduction of tones by singing. The vocal production of tones is, therefore, peculiarly adapted for the study of sensori-motor habits. While the sensory processes involved in such habits have been studied in detail, relatively little investigation has been made of the related motor processes. In a former paper the writer has shown some of the characteristics of sung tones and their changes under varying conditions of attention. Berlage (1) and Miles (7) have confirmed this work in some respects and expanded it in others.

The object of the investigation now presented was fourfold:

(1) To determine the relationship between ability to discriminate tones of a certain pitch and the ability to sing tones of the same pitch.

(2) To determine the changes which take place in the singing of tones of a certain pitch during the course of a long practice series.

(3) To determine what influence, if any, practice in singing

of a certain pitch has on the ability to discriminate tones (a) of the same pitch and (b) of a different pitch.

(4) To determine what effect, if any, practice in singing tones of a certain pitch has on singing tones of a different pitch.

For carrying out such an investigation it is necessary to have (a) a means of testing sensory discrimination of tones of different pitch; (b) a means of recording the pitch of a sung tone.

The difficulties of a method for the former purpose are well-known. Seashore's report (10) recommends the use of standard tuning forks of slightly different pitches and appropriate resonators. This method was not used in the present instance because of difficulty in obtaining forks of the range of the human (male) voice, and because of certain advantages of manipulation to be gained by the method actually adopted.

In the method used the source of the tones, both for purposes of testing discrimination and for reproduction by singing, was electric tuning forks. Four such forks, two of approximately 100 v. d. and two of approximately 225 v. d. frequency were used. These forks were placed in circuit with a single telephone receiver of the watch case variety, which was placed in a room adjoining that in which the forks were placed. The prongs of one of each pair of forks were fitted with adjustable weights by means of which the pitch was varied above or below that of the other fork of the same range, the pitch of the latter being kept constant. The variations in pitch were measured indirectly by noting the position of the weights on a millimeter scale attached to the base at one side of the fork. To facilitate the reading of the position of the weights one of them was provided with a pointer which projected to a point just above the scale. The pitch for the various readings on the scale was ascertained by placing the forks in circuit with an electric marker recording on a smoked paper belt.

The telephone and forks were connected by means of a Pohl commutator, the cross bars at the base having been removed. The semi-circular rods were kept out of the mercury cups when at rest by a pair of springs attached to the base. When the switch was in this position the circuit to the telephone was inter-

rupted. The current passed through the telephone and the standard fork when the free ends of the rods of the commutator were pressed in one direction, and through the telephone and variable fork when pressed in the opposite direction.

In the earlier investigation mentioned above there was used for the recording of sung tones a telephone receiver with mica diaphragm to which were attached magnifying levers. This method was discarded in the present investigation. A graphic record of the sung tone was obtained through the use of an ordinary voice key, similar to the Cattell model, but without any electro-magnetic attachment. The diaphragm is of very thin mica and is readily thrown into vibration by a tone sung into the air chamber. The voice key was placed in circuit with an electric marker of the Deprez pattern.

The sung tones were recorded on a long smoked paper belt running on two drums which were turned by hand. The time was recorded by an electric marker in circuit with a Kronecker interrupter regulated to intervals of 100 sigmas duration.

Before beginning the experiment the following preliminary tests were made:

(1) A test of the capacity of the telephone to register correctly the tone of the fork and respond to slight variations of tone. For this purpose recording levers were attached to the diaphragm of the telephone and the record thus obtained was compared with one obtained simultaneously from the fork through an electro-magnetic marker. There was no discoverable difference between the vibration rate of the fork and that of the telephone when recorded in this way.

(2) A similar test was made of the apparatus for recording the sung tones. A mica disk was attached to one of the prongs of the fork and placed in front of the air chamber of the voice key. In this manner records could be obtained of the vibration rate of the fork when transmitted through the voice key and comparison of these records with the records obtained at the same time through an electric marker showed no appreciable difference.

The tones obtained from the forks through the medium of the

telephone were not pure tones and differed somewhat in quality, especially in the case of the pair of forks of lower pitch. The intensities of the tones of each pair of forks were apparently the same. The qualitative differences did not remain constant, but varied with differences of adjustment of the forks, especially differences in the distance of the adjustable button from the spring of the fork. In order to ensure the best possible adjustment, the experimenter made use of a second telephone which could be connected with the forks by means of a switch. In this way he could test the tones at will and introduce such variations in adjustment as to secure better tones, when necessary.

At best, however, the qualitative differences were nearly always sufficient to enable the observer to distinguish the two tones. Great precautions had, therefore, to be taken in the discrimination tests to make sure that the results were due to differences in pitch and not differences in quality. Furthermore, on these and other grounds, all claims that the results give an absolute pitch limen for the subjects tested must be abandoned. It was sought only to obtain a limen which should hold under the conditions of this experiment and which should serve as a basis of comparison between the various observers who were tested.

The subjects who took part in the investigation were as follows: Professor Angier and Dr. Frost of the Yale Psychological Laboratory; Dr. Metcalf, laboratory assistant; and Messrs. Reed, Molby and Avey, graduate students in psychology. These subjects will be referred to hereafter as A., F., M., R., My., and Ay. respectively. All of these subjects except A. are of average or slightly more than average musical ability. M. and R. have had some training in the use of musical instruments, while My. and Ay. have been trained in singing to a slightly greater degree than the average person. A. and F. have had no musical training whatever. F. sings only infrequently. A. belongs to that class of individuals who cannot "carry a tune" correctly, though his inability in this respect is not as marked as in many cases.

All six subjects were given a preliminary test (1) of discrimination of pitch at both the higher and lower levels; (2) of ability to reproduce, by singing, tones of both the higher and lower

levels. Three of the subjects, A., F., and Ay., were then practised for a long time in singing the higher tone; the other three subjects, M., R., and My., were practised in the singing of the lower tone. After the practice in singing had stopped all subjects were re-tested as in the preliminary stage of the experiment.

In determining the capacity for pitch discrimination the following procedure was adopted. The observer sat in a partially darkened room with the telephone pressed lightly to the ear. A ready signal was given by means of a momentary flash of light from an electric lamp which was placed in front of the subject, but at some ten feet distance. A moment later the standard tone and the comparison tones were given for periods of two seconds each with a two second interval between them. The observer made known his judgment by pressing a key which was connected with a sound hammer in the experimenter's room. Judgments were classified as (1) same or doubtful; (2) higher; or (3) lower.

The pitch of the variable fork was varied by gradual steps below that of the standard fork and the threshold was regarded as having been reached at the point where the observer gave five correct judgments in succession. To avoid as far as possible unintentional judgments on the basis of the differences in quality of the two tones the standard tone was frequently given after the comparison tone. Furthermore, when it appeared that the threshold had been reached, the pitch of the variable fork was occasionally made higher instead of lower than that of the standard. In this way the experimenter could test whether the observer was meeting the requirements of the experiment by relying solely on differences of pitch in making his judgments. If it was found that this was not the case, as happened in several instances, the observer was cautioned and usually adopted a more critical attitude toward his judgments. Before recording any results in these experiments two periods of about twenty minutes each were allowed each observer for adaptation to the conditions of the experiment. The results of the preliminary test of discrimination of pitch follow (Table I).

The table gives the discrimination thresholds in vibrations per

second at both lower and higher pitches for each of the six subjects. Five trials on different days were made for each subject. In most cases the subjects expressed themselves as having no difficulty in distinguishing between the pitch and qualitative differences of the tones. In some instances, however, there was so much confusion that the test for that day was abandoned. While the confusion manifested may have been aggravated by the qualitative differences in the forks, it cannot be wholly charged to this cause, since other investigators have found similar results under more ideally perfect conditions.

TABLE I

Discrimination—Threshold before practice.

	Low (S = 100.3 V.D.)						High (S = 225.1 V.D.)					
	A.	F.	Ay.	M.	R.	My.	A.	F.	Ay.	M.	R.	My.
1.	1.9	1.9	1.9	1.3	1.3	1.9	3.2	2.6	2.6	2.0	2.6	2.6
2.	2.4	2.4	1.9	1.9	1.3	1.9	3.2	2.6	2.0	2.0	2.6	2.0
3.	2.4	1.9	2.4	1.3	1.3	1.9	3.8	2.6	2.0	2.0	2.6	2.0
4.	2.4	2.4	2.4	1.3	1.3	1.3	3.8	2.6	2.0	1.5	2.6	2.0
5.	1.9	2.4	2.4	1.9	1.3	1.9	3.2	2.6	2.0	1.5	2.6	2.0
Av.	2.2	2.2	2.2	1.4	1.3	1.8	3.4	2.6	2.1	1.8	2.6	2.1
A.D.	0.2	0.2	0.2	0.3	0.0	0.2	0.3	0.0	0.2	0.2	0.0	0.2

It will be seen from the table that the thresholds are greater for the higher than for the lower level. The average for all subjects at the lower level is 1.9 and for the higher level 2.4. These results agree with those of other investigators who have found that the threshold for pitch discrimination at various ranges does not increase proportionally to the vibration rate of the tones.

It will be noted that A., who is the decidedly unmusical subject, gives a record for pitch discrimination which does not differ largely from the records of the other subjects. At the lower level his average discrimination is the same as that of the other subjects. A.'s discrimination at the higher level is the highest of the six records, but it is not greatly different from that of two of the others.

In carrying out the experiments in singing the subject was given a ready signal (light) and a moment later the tone of the standard fork was sounded for two seconds. The subject was instructed to wait a moment after the tone stopped sounding and then sing into the mouthpiece a tone of the same pitch and ap-

proximately the same duration. Berlage and Miles have found that the pitch of a sung tone is somewhat modified by the vowel sound used in singing. The singer was, therefore, instructed to modulate his voice to the vowel sound "a" as in "ah." After allowing a few trials for the sake of adapting the subject to the condition of the experiment, five records were obtained from each of the subjects for each of the two tones. The records were read by means of the apparatus described in the former paper and in a similar manner to that of the earlier investigation. The results, expressed in vibration rate per second for each succeeding period of a tenth of a second's duration, are given in Table II. Figures are given for only the first second during which the tone was sung as this period is fairly representative of the whole tone.

In the column marked pitch is given the vibration frequency per second of each tenth of second for a continuous period of one second from the beginning of the tone. The figures given represent, therefore, the actual number of vibrations on the record multiplied by ten, so as to express the pitch for each period of 100 sigmas in the conventional unit of number of vibrations per second. Since the first two or three-tenths of second of the tone are marked periods of adjustment they do not represent the main tone correctly. Two averages are, therefore, given; the first for the earlier two or three-tenths of second, and the second for the remainder of the tone. An examination of the figures for the earlier part of the tone shows that this average is usually, though not invariably, lower than that for the rest of the tone. Usually the singer begins much lower than the final average and in two or three-tenths of second reaches a pitch much higher than the one to which he finally settles down. This process of sliding up to the tone is much less marked in singing the lower tone and at times it seems as if the process were reversed in these tones, the singer beginning too high and sliding down to the pitch finally adopted. The upper of the two figures in the third column for each tone gives the extreme variation of these earlier tones (the difference between the highest and lowest pitch). Besides this lack of uniformity in the earlier part of the

tone there are other though usually less marked variations in the pitch from any given one-tenth of a second to the next throughout the rest of the tone. The lower of the two figures in the third column for each tone gives the average deviation for the latter part of the tone and is, therefore, a measure of the degree of lack of uniformity of pitch in the main tone.

Turning from these general features of Table II to the individual results, it will be seen that all the subjects show much lack of uniformity both in beginning the tones and in continuing them. Roughly, the amount of this lack of uniformity is proportional to the vibration frequency; the variations in the higher tones being much greater than in the lower. Subjects A., F., and My. are not even approximately correct in singing the low tone, but in all other cases there is a fair degree of approximation to the standard. In these cases it seems clear that the difficulty is to be accounted for in large measure by the inability of the

TABLE II

Singing before practice.

Subject A.

Low Tone (S = 100.3 V.D.)

I			II			III			IV			V		
Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.
140			140			133			119			127		
140			149	144.5	9	149	141	16	141	130	22	129		
149	143	9	143			147			142			131	129.0	4
153			149			152			156			128		
146			148			147			149			126		
144			148			148			151			127		
148			148			149			150			129		
146			146			146			150			127		
146			148			148			151			127		
148	147	2.0	145	146.8	1.7	149	148.3	1.3	155	149.3	2.4	129	127.6	1.2
High Tone (S = 225.1 V.D.)														
188			180			185			175			172		
202			215			211			224	199.5	49.	215	47	18.2
210	200.0	32	218	204.3	38	220	253.3	35	224			219		
213			216			218			220			216		
217			224			215			220			219		
216			220			220			220			216		
215			216			215			220			215		
219			215			220			218			217		
217			215			215			218			218		
217	217.7	1.8	217	217.6	2.5	215			215	219.4	1.8	215	216.6	1.2
						218								
						218	217	1.8						

Subject F.

Low Tone (S = 100.3 V.D.)

I			II			III			IV			V		
Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.
143			134			121			150			125		
150	146.5	7	143			139			140			133		
140			150	142.3	16	148	136	27	146	145.3	4	146	134.7	21
144			151			144			146			141		
141			152			146			143			142		
143			143			144			146			143		
141			144			142			143			146		
140			143			145			143			145		
145			150			141			147			145		
143	142.1	1.8	145	146.9	3.6	142	144.9	1.8	143	144.4	1.9	143	143.6	1.5
High Tone (S = 225.1 V.D.)														
187			152			168			171			190		
213			178			201			209			216		
227	209	40	197	175.6	45	219	196.0	51	215	198.3	44	220	208.3	30
216			220			220			212			214		
220			222			218			214			226		
217			220			218			218			216		
219			217			220			218			218		
220			223			217			220			220		
220			215			219			217			220		
219	218.7	1.5	221	221.9	3.0	220	218.9	0.9	219	216.8	2.2	220	219.1	2.7

Subject Ay.

Low Tone (S = 100.3 V.D.)

I			II			III			IV			V		
Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.
112			105			106			116			110		
109			103	104	2	107	106.5	1	107	111.5	9	107	108.5	7
96	105.7	16	109			110			103			113		
117			108			109			105			108		
105			107			104			107			111		
105			108			106			109			110		
102			106			109			103			104		
102			104			106			108			109		
105			106			109			107			106		
108	106.3	3.6	108	107.0	1.3	108	107.6	1.8	107	106.1	1.9	109	108.8	2.1
High Tone (S = 225.1 V.D.)														
179			221			219			236			222		
231			230	225.5	9	228	223.5	9	228			234	228.0	12
219	209.7	40	211			216			217	223.7	19	220		
218			221			227			221			228		
223			221			225			223			221		
226			221			228			219			221		
219			221			223			226			230		
224			230			227			219			225		
221			223			224			223			229		
224	222.1	24	213	221.0	3.6	222	224.0	2.6	218	223.7	2.3	225	224.9	3.1

Subject M.

Low Tone (S = 100.3 V.D.)

I			II			III			IV			V		
Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.
101			98			85			85			109		
99			103	100.5	5	90			101	93	16	112	110.5	3
98	99.3	3	103			100	91.6	15	101			108		
95			106			101			100			108		
101			102			95			99			103		
100			103			100			97			108		
100			101			99			100			108		
103			100			99			99			102		
103			102			101			101			109		
103	102.1	2.2	105	102.8	1.6	102	99.6	1.6	102	99.9	1.2	109	106.9	2.1

High Tone (S = 225.1 V.D.)

I			II			III			IV			V		
Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.
230			221			201			218			225		
222	226	8	227			226			220	219	2	220	222.5	5
225			233	227	12	228	218.3	27	220			220		
221			228			229			222			222		
225			224			221			219			219		
220			225			221			223			223		
228			220			222			221			221		
225			224			221			224			224		
222			221			224			220			220		
226	224	2.3	228	224.3	2.3	220	222.6	2.3	224	221.6	1.6	224	221.6	1.6

Subject R.

Low Tone (S = 100.3 V.D.)

I			II			III			IV			V		
Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.
105			102			107			105			101		
110			102			99			107			102		
115	110.0	10	105	103.0	3	100		8	109	107.0	4	102	101.7	1
112			107			105			110			103		
116			106			107			110			103		
112			106			107			110			101		
115			107			105			109			103		
116			104			107			112			101		
115			102			108			112			104		
112	114.0	1.7	105	105.4	1.4	109	106.0	2.0	110	110.5	1.6	100	102.1	1.3

High Tone (S = 225.1 V.D.)

I			II			III			IV			V		
Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.
177			215			220			186			220		
190			229	222.0	14	229			210			232	228	12
212	193.0	35	224			235	228.0	15	218	204.6	32	230		
216			234			235			222			235		
224			231			231			229			230		
218			235			236			226			232		
220			230			239			230			228		
225			238			237			228			235		
217			234			238			230			232		
220	220	3.0	238	233.0	3.5	240	236.6	2.1	233	228.3	2.5	230	231.5	2.0

Subject My.

Low Tone (S = 100.3 V.D.)

I			II			III			IV			V		
Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.
121			110			118			113			119		
120	120.5	1	112			119			114			116		
121			114	112.0	4	120	119.0	2	118	115.0	5	119	117.5	3
122			114			122			119			118		
121			118			122			120			121		
120			118			122			119			118		
122			119			121			119			120		
120			120			120			120			120		
120			119			122			120			121		
123	121.2	0.9	120	118.3	1.4	120	121.3	0.8	120	119.6	0.5	120	119.6	1.0
High Tone (S = 225.1 V.D.)														
215			215			214			209			221		
225			225			217			215			224	227.5	3
226	220.0	10	225	220.0	10	224	218.3	10	220	214.7	11	222		
226			226			221			217			225		
225			226			223			221			227		
224			226			221			221			223		
228			218			221			219			223		
226			224			223			224			226		
224			222			221			219			222		
220	224.9	1.9	225	224.0	1.8	222	221.7	0.8	221	219.7	1.8	225	224.2	1.6

singer to distinguish the fundamental tone. Indeed, it would appear from the results that A. and F. are perhaps both responding to a prominent overtone.

In carrying out the practice series of experiments subjects A., F., and Ay. were practiced in the singing of the low tone. These practice experiments consisted in the singing of the standard in the manner already described twenty times daily for a period extending over several months. In this way a total number of approximately one thousand tones were sung by each subject. M., R., and My. were practiced in a similar manner with the high tone. When the practice period was about half finished the method was somewhat modified. The subjects were now asked to sing the tone while the standard tone was still sounding. At this point in the experiment and, indeed, from near the beginning of the practice series, all the subjects, except A., were approximating the standards. Singing the tone in unison with the standard resulted in some improvement with the other subjects, but A's. record continued to be very irregular and inaccurate.

In A's. case, therefore, a more radical attempt was made to obtain exactness of reproduction of tone. The tone of the standard fork was now made by striking the fork with a rubber hammer and reinforced by an appropriate resonator. Under these conditions A. responded with tones which were more nearly the tone of the standard, but very inconsistently and with no close approximation of the standard tone, although persistent attempts to obtain correct results were made.

Before obtaining the final results of singing the standard tones after practice, one hundred practice trials were made in the manner originally adopted—that is, with a pause between the standard tone and the beginning of the singing. The results of the final series of five tones at both levels for each of the subjects are shown in Table III.

For more convenient comparison, the results of Tables II and III are condensed in Table IV. Columns V_1 represent the average deviation of the sung tones from the standard before and

Subject A.

TABLE III

Singing after practice.
Low Tone (S = 100.3 V.D.)

I			II			III			IV			V		
Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.
122			118			115			118			113		
120	121.0	2	118			118			120	119.0	2	116	114.5	3
120			113	149.7	5	121	118.0	6	119			113		
118			118			117			119			117		
120			120			119			120			118		
120			116			120			117			113		
119			117			117			118			114		
116			119			121			120			113		
120			118			117			119			112		
118	118.9	1.2	115	117.6	1.3	119	118.5	1.3	118	118.7	0.9	115	114.4	1.3
High Tone (S = 225.1 V.D.)														
153			141			148			144			143		
167			166			182			169			172		
175	165.0	22	173	160.0	32	183	171.0	35	175	162.7	31	176	163.7	33
170			175			179			178			165		
172			178			175			180			170		
174			181			180			177			170		
172			175			178			181			172		
172			176			180			178			170		
172			174			176			180			173		
173	172.1	0.8	178	176.7	2.0	180	178.3	1.7	176	178.6	1.7	174	170.6	2.1

Subject F.

Low Tone (S = 100.3 V.D.)

I			II			III			IV			V		
Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.
98			99			103			104			99		
100			100			103			102			101		
102	100.0	4	103	100.7	4	102	102.7	1	102			103	101.0	4
102			102			103			101			104		
102			103			103			101			102		
101			102			103			101			102		
102			103			103			102			102		
104			103			103			102			103		
104			104			104			102			102		
103	102.6	0.9	102	102.7	0.6	104	103.3	0.4	103	102.0	0.5	103	102.6	0.7
High Tone (S = 225.1 V.D.)														
200			192			210			207			215		
212			219			218			210			220	217.5	5.0
227	213.0	27	221	210.7	29	220	216.0	10	220	212.3	13	220		
222			221			220			222			220		
221			221			221			220			223		
221			215			221			222			222		
221			223			220			222			222		
223			220			221			222			220		
222			225			222			220			221		
222	221.7	0.6	222	222.4	1.6	220	220.7	0.6				223	221.4	1.1

Subject Ay.

Low Tone (S = 100.3 V.D.)

I			II			III			IV			V		
Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.
99			102			101			98			98		
100	99.5	1	103	102.5	1	100	100.5	1	95	96.5	3	99	98.5	1
100			102			101			100			98		
99			102			98			101			98		
100			100			100			101			98		
100			100			100			102			98		
100			98			98			102			99		
101			100			101			101			99		
101			100			101			99			99	98.8	0.7
100	100.1	0.4	101	100.4	1.0	100	99.9	0.9	101	100.9	0.7	101		
High Tone (S = 225.1 V.D.)														
210			191			210			217			215		
216			220	215.5	19	220	215.0	10	220	218.5	3	219	217	4
219	215.0	9	222			218			220			218		
225			220			221			220			220		
220			218			220			220			220		
219			222			220			220			220		
217			220			220	220.0	0.1	219			220		
220			221						221			218		
219			221			220			221			222		
220	220.0	1.4	219	220.0	1.1	221			219	220.0	0.1	219	219.6	1.0
						220								

Subject M.

Low Tone (S = 100.3 V.D.)

I Pitch	I Av.	I Dev.	II Pitch	II Av.	II Dev.	III Pitch	III Av.	III Dev.	IV Pitch	IV Av.	IV Dev.	V Pitch	V Av.	V Dev.
96			99			99			98			95		
100	98.0	4	105	102.0	6	101	100.0	2	100	99.0	2	103	99.0	8
92			100			98			99			101		
94			100			102			100			100		
95			100			102			101			100		
96			97			100			103			101		
99			99			102			102			101		
99			98			103			103			100		
97			101			102			103			102		
94	95.8	2.0	99	99.3	1.0	102	101.4	1.2	101	101.5	1.3	101	100.8	0.6

High Tone (S = 225.1 V.D.)

I Pitch	I Av.	I Dev.	II Pitch	II Av.	II Dev.	III Pitch	III Av.	III Dev.	IV Pitch	IV Av.	IV Dev.	V Pitch	V Av.	V Dev.
210			220			210			220			212		
218			220			221			230	225	8	223	217.5	11
226	214.7	16	224	221.3	4	222	217.7	12	219			223		
227			225			223			225			223		
229			225			222			224			222		
229			225			224			224			223		
227			226			224			223			224		
228			225			225			223			224		
227			225			225			225			223		
225	227.4	1.1	225	225.1	0.2	227	224.3	1.2	225	223.5	1.4	224	223.3	0.7

Subject R.

Low Tone (S = 100.3 V.D.)

I Pitch	I Av.	I Dev.	II Pitch	II Av.	II Dev.	III Pitch	III Av.	III Dev.	IV Pitch	IV Av.	IV Dev.	V Pitch	V Av.	V Dev.
105			107			107			105			109		
106	105.5	1	103	105.0	4	107			107	106.0	2	106	107.5	3
104			108			108	107.3	1	106			108		
105			109			107			107			109		
102			106			106			107			107		
103			108			105			108			109		
107			107			106			107			109		
102			109			107			108			108		
102			105			105			108			109		
102	103.4	1.5	105	107.1	1.4	105	105.9	0.7	106	107.0	0.7	109	108.5	0.6

High Tone (S = 225.1 V.D.)

I Pitch	I Av.	I Dev.	II Pitch	II Av.	II Dev.	III Pitch	III Av.	III Dev.	IV Pitch	IV Av.	IV Dev.	V Pitch	V Av.	V Dev.
220			215			216			219			219		
223			220			225			223			222		
225	222.7	5	221	218.7	6	228	223.0	12	225	222.3	6	224	221.7	5
228			225			228			223			222		
225			225			229			225			224		
228			225			230			224			224		
225			226			229			224			224		
228			225			229			226			226		
228			227			230			226			223		
229	227.3	1.3	228	225.7	1.0	228	229.0	0.1	228	225.0	1.3	225	224.0	0.1

Low Tone (S = 100.3 V.D.)

Subject My.

I			II			III			IV			V		
Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.	Pitch	Av.	Dev.
141			141			137			148			140		
143	142	2	144	142.5	3	145	141	8	143			138		
140			139			137			138	143.0	10	145	139.0	2
150			148			142			142			148		
146			139			142			146			142		
142			143			143			141			145		
143			140			143			146			145		
147			146			142			145			140		
143			142			138			142			143		
143	144.3	2.1	142	142.6	2.8	145	141.5	2.0	143	143.6	1.8	142	143.8	2.1
High Tone (S = 225.1 V.D.)														
231			228			230			229			218		
239	235.0	8	228			222			227			213	215.5	5
237			225	227.0	3	228	226.0	8	224	226.7	5	220		
232			226			223			227			213		
231			231			226			221			222		
229			230			224			230			211		
224			225			227			230			221		
228			228			223			223			216		
230			224			220			229			218		
228	229.9	2.6	227	227.3	2.1	229	225.1	2.4	222	226.0	3.4	212	216.6	3.6

TABLE IV

Subj		Low			High		
		V_1	V_2	V_3	V_1	V_2	V_3
A	Before	43.5	1.7	1.2	7.4	1.8	40.2
	After	17.3	1.2	3.6	49.8	1.7	30.6
F	Before	44.0	2.1	15	6.0	2.1	42.0
	After	2.3	0.6	3	3.7	1.0	17.0
Ay	Before	6.9	2.1	7	2.0	2.8	17.8
	After	0.6	0.8	1.4	5.2	0.8	9.0
M	Before	2.4	1.8	8.4	2.3	2.2	10.8
	After	1.7	1.2	4.4	1.3	0.9	10.2
R	Before	7.3	1.6	5.2	6.8	2.6	21.6
	After	6.1	1.0	2.2	1.6	0.8	6.8
My	Before	19.7	0.9	3.0	2.2	1.6	8.8
	After	6.9	2.2	5.0	3.3	2.8	5.8

after practice for both high and low tones. In arriving at these averages the earlier two or three-tenths of a second of the tone were not taken into account since, as we have already seen, they are not representative of the tone as a whole, but of a period of initial adjustment. Columns V_2 give the average of the mean variations of the five tones for each subject before and after practice. These figures, therefore, represent the degree of the

steadiness of the tone as a whole, disregarding as before the initial period. In columns V_3 are arranged the average of the variations at this initial period for the five high and five low tones before and after practice. The figures of V_1 show that A., F., and Ay., who practiced with the low tone, reduced the error in singing at that level. In the case of A., however, the improvement is more apparent than real, for at no time does he approximate the standard. His records from day to day show no gradual improvement as in the case of the other subjects and no constancy of results. The introspective records show that this subject toward the end of the practice series responded in a hit-or-miss fashion with a tone near the lower level of his voice register. When this subject began his practice on any given day with a sung tone of a certain pitch, his subsequent tones were usually of about the same pitch. This tendency to persist in repeating a tone of the same pitch when once begun was found to be characteristic of non-musical subjects in my former study of singing reactions (3) and also in the work of Miles (7). It would appear that such persons in the absence of complete organization of the auditory and vocal motor factors rely mainly upon a memory of the kinaesthetic sensations as cue to further reproductions of the tone.

In the case of F. who began with an error as great as that of A. and in the same direction, a tone was sung on the second day of practice which approximated the standard and improvement thereafter was of a steady character, quite in contrast with the erratic nature of A.'s record. Ay. began with a tone approximating the standard and made steady improvement.

M., R., and My. were practiced in the singing of the high tone. M. and R. made consistent improvement in the amount of error. The figures given for My. seem to indicate a lack of capacity for training with the high tone of a similar nature to that found in the case of A. with the low tone. The similarity, however, does not hold in one respect. My.'s results were, indeed, erratic during the course of practice but he frequently approximated the standard to a much higher degree than did A. This was especially true of that part of the practice series during which the

singing took place simultaneously with the sounding of the standard fork. Indeed, it was true of all the subjects except A. that a marked improvement took place during this part of the practice series. In the case of My., however, this improvement was not carried over when the original conditions were restored, while in the other cases it was.

At the end of the practice series, then, F., Ay., M. and R. had made improvement in the singing of tones of the pitch on which they had practiced. At this stage the average errors, respectively, for these subjects amounted to 2.3%, 0.6%, 0.6%, 0.7% of the standards.

Turning now to a consideration of the effects of the practice on the singing of tones at a different level, it will be seen that of those who improved in the practice series F., M. and R. made a slightly smaller amount of error in these non-practiced tones after practice than before practice, while Ay. did worse. There is, therefore, little evidence of transference of practice effects in the accuracy of singing from one pitch to another.

The direction of the error represented by the figures in column V_1 is not indicated in the table, these figures being the arithmetical average of errors. A detailed study of this point shows, however, that there is a general tendency to sing the lower tone too high, and the higher tone too low. This statement is unequivocally true of the tones sung by A., F., M. and Ay., both before and after practice. In the case of R. both the low tone and the high were sung too high before and after the practice series. My. always sang the low tone too high but sang the high tone too low before practice and too high after practice. Miles (7) found a general tendency to sharp in male subjects but the fact that his standard tones covered a narrower range within easy compass of his subjects' voices made his results scarcely comparable with our own.

Seashore and Jenner (9) report improvement in accuracy of singing tones after practice with visual control by means of the Seashore tonoscope. In these experiments the improvement apparently transfers to tones of a different pitch from those practiced. That there should be more evidence of transfer under

such conditions where the visual control gives a knowledge of results might be expected from other experiments in transfer (4), (6), (8).

A comparison of columns V_2 and V_3 before and after practice shows improvement in approximation to uniformity of tone both for the tones which were practiced and those which were not in almost all cases. The only exception is in the case of My., all of whose tones were less uniform after practice than before. The improvement with respect to uniformity is not marked in the case of A. and also in the case of M.'s high tones so far as the extreme variations at the beginning of the tone are concerned (V_3).

Berlage (1) has found that the deviations from period to period are less when the reproduced tone is sung in response to one's own sung tone than when the standard tone is the sung tone of another person. He also found that the deviations are greater when the tone is sung freely without any attempt to approximate a standard than it is under either of the conditions just mentioned. It seems, therefore, that the steadiness with which a tone is maintained is not a purely physiological phenomenon of muscular tetanus but that it varies with the psychological conditions and is subject to improvement through practice. Furthermore, the effects of practice, so far as steadiness is concerned, are transferred to tones of a different pitch from those practiced, as my present investigation shows. The same statement applies to the larger deviations at the beginning of the tone.

It remains to give the results of the tests for discrimination after the practice series of experiments. These tests were given in the same way as those made before practice. The results are given in Table V and the average results before practice are added for purposes of comparison.

This table shows that F., Ay., M. and R. have lower thresholds of discrimination at the level at which practice in singing took place than was the case before practice. This improvement is, however, not extended to the other non-practiced level. It will be remembered that these subjects all made unequivocal improvement in the amount of error made in singing their standard

TABLE V
Discrimination-Thresholds after practice

	Low						High					
	A.	F.	Ay.	M.	R.	My.	A.	F.	Ay.	M.	R.	My.
1.	2.4	.9	1.3	1.9	1.3	2.4	3.8	2.0	2.0	1.1	1.1	2.0
2.	2.4	1.3	1.3	1.9	1.3	1.9	3.8	2.6	2.0	0.5	1.5	2.6
3.	2.4	0.9	1.3	1.3	1.3	1.9	2.6	2.0	2.0	0.5	1.5	2.6
4.	1.9	0.9	1.3	1.9	0.9	1.9	3.2	2.6	2.0	0.5	1.5	2.0
5.	2.4	1.3	1.3	1.9	1.3	1.9	3.2	2.6	2.0	0.5	1.5	2.0
Av.	2.3	1.1	1.3	1.8	1.2	2.0	3.3	2.4	2.0	0.6	1.4	2.2
Before Practice	2.2	2.2	2.2	1.4	1.3	1.8	3.4	2.6	2.1	1.8	2.6	2.1

tones. In the case of A. and My. no improvement is shown in the pitch discrimination after practice in singing. As has already been shown these subjects made no real progress in the reduction through practice of the error in singing the standard tone.

Comparing tables IV and V it is found that in general the figures expressing sensory discrimination are lower than the corresponding figures for the sung tones. This is true in all but three of the twenty-four pairs of results. In the three cases where this is not true, the figures are practically the same. It would, therefore, appear that fineness of discrimination is more accurate than motor reproduction. This point becomes very marked when it is remembered that the figures given for sensory discrimination are probably much higher than would have been obtained from tests of sensory discrimination given under the more standardized threshold conditions.

An inspection of the figures would lead us to expect little correlation between sensory discrimination and accuracy of reproduction for the same tone. Calculated by the Pearson products-moment method the index of correlation is .37 with a probable error of .023. Miles (7) found the index of correlation between accuracy of singing and pitch discrimination for eighty-two male subjects to be only .33. The most marked lack of correlation between accuracy of reproduction and sensory discrimination is in the cases of A. and F., the subjects who made little or no improvement in accuracy of singing but who nevertheless are not noticeably different from the others in the results of the discrimination tests. That practice results in a lowering of the threshold of pitch discrimination has been reported by

Seashore (10) and also Smith (11). Seashore distinguishes a so-called "cognitive" threshold from a "physiological" threshold and holds that the cognitive threshold only is subject to improvement through practice. It is clear, however, that the physiological threshold is a somewhat theoretical limit. It must be admitted, however, that the threshold found in this investigation is a "cognitive" threshold found under special conditions. The subjects were required to be certain not only of a difference in pitch but of the direction of the change. While this kind of cognitive threshold, therefore, was peculiarly subject to improvement by practice, it seems nevertheless true that the improvement which actually took place was due to the practice in singing rather than to adaptation, attention, interest, or other factors. Such factors would presumably be operative to as great a degree at the non-practiced level as at the level at which practice took place but, as we have seen, the improvement was not transferred from one level to another, either in the singing or sensory discrimination.

The results of the present study tend to confirm the objections that have been made to those so-called motor theories which regard kinaesthetic sensations as playing the fundamental rôle in such responses. The results show that motor reactions to tones are by no means so accurate as the sensory discrimination. Judd's study of the eye-movements in the perception of the Müller-Lyer illusion (5) gave analogous results. He found that there was an intimate relationship between the character of the eye movements and the amounts of illusion, and also that both the eye-movements and the amount of illusion changed with practice. Nevertheless, the movements are of such a nature as to preclude the probability that the resultant kinaesthetic sensations are the cause of the illusion.

On the other hand, there is agreement between these results and those of other previous investigations which have shown the closeness of the relationship between sensory and motor processes—a relationship involving motor organization rather than mere kinaesthetic sensations. In my earlier investigation it was shown that the motor reactions to tones are

intimately related to all the forms of harmony and discord. Bingham's investigations (2) have led him to the conclusion that melody is related to the "upsetting of established muscular tensions," "the organization of incipient responses," and the merging of balanced tensions. Stetson (12) has found similar tension-relaxation processes in his experimental study of rhythm. The facts here presented point to the organic unity of motor and sensory factors in even so relatively simple a process as sensory discrimination of tones. With the development of more precise and unvarying modes of response to one tone, there arises a greater keenness in discriminating that tone from all others. Sensory discrimination must, therefore, be regarded as related to the organization which has taken place with reference to the new mode of response.

SUMMARY OF RESULTS

(1) There is no marked correlation between the initial capacities of the subjects tested for discrimination of tones and ability to reproduce these tones accurately by singing. A subject (A) whose "ear" is little inferior to that of the other subjects is nevertheless totally at a loss to sing the tones accurately.

(2) Practice in singing tones of a certain pitch resulted in marked reduction in the error of reproducing those tones in the case of four of the six subjects.

(3) Slight improvement in singing tones of a pitch different from the one practiced was made by three of those four subjects and no improvement by the other.

(4) Practice resulted in improvement in steadiness both at the initial point of the sung tone and throughout the tone as a whole in the case of those subjects who improved in accuracy.

(5) Improvement in steadiness was also shown in the singing at the non-practiced level.

(6) Subjects who improved in accuracy of singing tones of a certain pitch improved also in discrimination of tones at that level.

(7) There was no improvement for such subjects in the discrimination of tones of a different pitch from that practiced.

(8) Subjects who did not improve in accuracy of singing made no improvement in discrimination.

REFERENCES

1. Berlage, F. Der Einfluss von Artikulation und Gehör beim Nachsingen von Stimmklangen. *Psychol. Stud.*, 1910, **6**, 39-140.
2. Bingham, W. V. Studies in melody. *Psychol. Rev., Monog. Suppl.*, 1910, **12**, 1-88.
3. Cameron, E. H. Tonal reactions. *Psychol. Rev., Monog. Suppl.*, 1907, **8**, 227-300.
4. Judd, C. H. Practice and its effects on the perception of illusions. *Psychol. Rev.*, 1902, **9**, 27-39.
5. Judd, C. H. The Müller-Lyer illusion. *Psychol. Rev., Monog. Suppl.*, 1905, **7**, 55-81.
6. Judd, C. H. Practice without knowledge of results. *Psychol. Rev., Monog. Suppl.*, 1905, **7**, 185-198.
7. Miles, W. R. Accuracy of the voice in simple pitch singing. *Psychol. Rev., Monog. Suppl.*, 1914, **15**, 13-66.
8. Ruediger, W. C. Improvement of mental functions through ideals. *Ed. Rev.*, 1908, **36**, 364-371.
9. Seashore, C. E., and Jenner, E. A. Training the voice by the aid of the eye in singing. *J. of Educ. Psychol.*, 1910, **1**, 311-320.
10. Seashore, C. E. The measurement of pitch discrimination: a preliminary report. *Psychol. Monog.*, 1910-11, **13**, 21-60.
11. Smith, F. O. The effect of training in pitch discrimination. *Psychol. Rev., Monog. Suppl.*, 1905, **7**, 67-103.
12. Stetson, R. H. A motor theory of rhythm and discrete succession. *Psychol. Rev.*, 1905, **12**, 250.

AN EXPERIMENTAL STUDY OF THE CONSCIOUS ATTITUDES OF CERTAINTY AND UNCERTAINTY

By John Trumbull Metcalf, Ph.D.
Instructor in Psychology
Smith College

The object of the present investigation is an analysis of the conscious attitude (*Bewusstseinslage*) on the motor side. The effort is made to determine whether certain regular forms of bodily reaction accompany the subjective attitude of certainty, and whether with changes in subjective attitude there are corresponding changes in the forms of such reaction. The subject is given a task which he carries through in response to certain instructions. The motor processes immediately involved in carrying through this reaction to the instructions are recorded by the apparatus, and at the end of each experiment the subject gives a complete introspective report. These two records, the objective record of the form of the reaction and the introspective record of the conscious processes experienced during the reaction, are examined together to see if there is any correspondence between them. The tasks chosen for the investigation consist in the making of drawing movements with the hand out of sight. The apparatus gives records of the accuracy of these movements, and of all changes in rate and pressure which occur during the process. Variations are introduced to determine whether by changing the instructions in such a way as to modify the objective form of the reaction a corresponding change may be produced in the subjective attitude.

The conscious attitude has come to hold a very important place in psychological theory, and a good deal of work has been directed toward analyzing it by the introspective method. Yet, to the writer's knowledge, no attempt has been made to attack it on the motor side. The present investigation attempts this, its object being to find out whether the introspectively given attitude of certainty involves a definite form of motor reaction on the part of the subject, and a change in the attitude a change in the form of such reaction. The method used is an extension of that which has already been employed in the investigation of the relation between motor processes and consciousness. Judd (2) has shown that the character of perception and attention is closely connected with motor processes. The present work follows the

same method, extending it to that phase of consciousness which experimenters in the field of the higher thought processes have called the "*Bewusstseinslage*" or conscious attitude. This investigation is, therefore, more closely related to the experimental work on the relation between movement and consciousness than it is to the almost exclusively introspective experimental investigations of the higher thought processes.

The first requisite in an investigation of this sort is a motor process, simple enough to be measured objectively, and yet sufficiently difficult of performance to yield the necessary richness of introspective data. The making of simple drawing movements with the hand hidden from sight was chosen as the task. These drawing movements were measured by the apparatus, and after each drawing full introspections were given by the subject and taken down by the experimenter. The drawings were made in response to certain instructions, and in the course of carrying out the process various attitudes appeared, as reported in the introspections. Now if there is any relation between attitude and motor processes in general the attitudes reported here must be connected with the particular motor processes measured by the apparatus, because both attitude and the processes measured come of necessity in response to the instructions. In other words, the motor processes, i. e., the drawing movements, measured by our apparatus are necessarily involved in carrying out the instructions, and are therefore particularly relevant to any attitudes consequent upon the instructions.

The apparatus for measuring the drawing movements was that used by Freeman in his analysis of writing movements (1). The two cuts of the apparatus which appear there are reprinted here (Figs. 1 and 2).

This apparatus yields three objective records of the drawing movements. In the first place there is the actual drawing made by the subject upon the primary sheet. The task was usually the copying of a simple geometrical figure—the "model." Thus when the drawing is measured for straightness of lines, length of lines, size of angles, etc., and these measurements compared with the corresponding measurements of the model, a record of

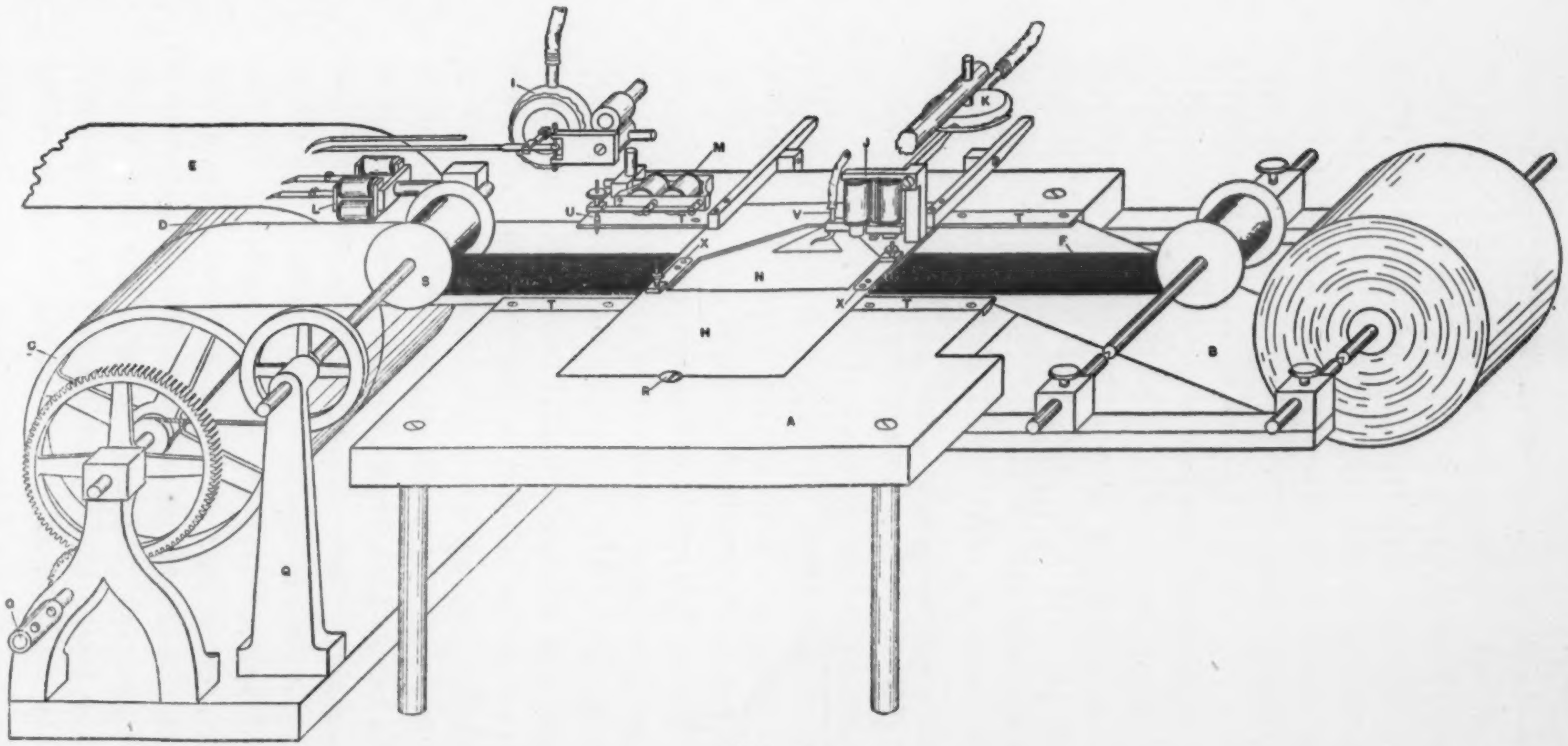


FIG. 1.

The primary sheet on which the reactor draws is fixed under the hinged plate, H (see also Fig. 2), and is exposed through the opening of the plate, N, to form the surface on which the drawings are made. Below this sheet runs the moving strip, B, for the time record, and between sheet and strip runs the type-writer ribbon, F, at a much slower rate. The original drawing and the secondary drawing made through the type-writer ribbon on the moving strip, are correlated through the two pencil-points, XX, which project through two holes in the plate, H, and make two dots on the primary sheet and two lines on the moving strip. The first time-marker, J, writes through a hole in the primary sheet directly upon the moving strip. Below the opening, N, is the hingedplate, C (Fig. 2), and this plays upon the lever which is connected with the tambour, K. In our arrangement the tambours, K and I, were removed, and another pressure-recording device substituted. (See text.) E is the smoked strip for the pressure record, and L the second time-marker, in circuit with the first. D is the drum for the pressure record, and C the drum which unrolls the moving strip. The marker, M, not needed in these experiments, was removed.

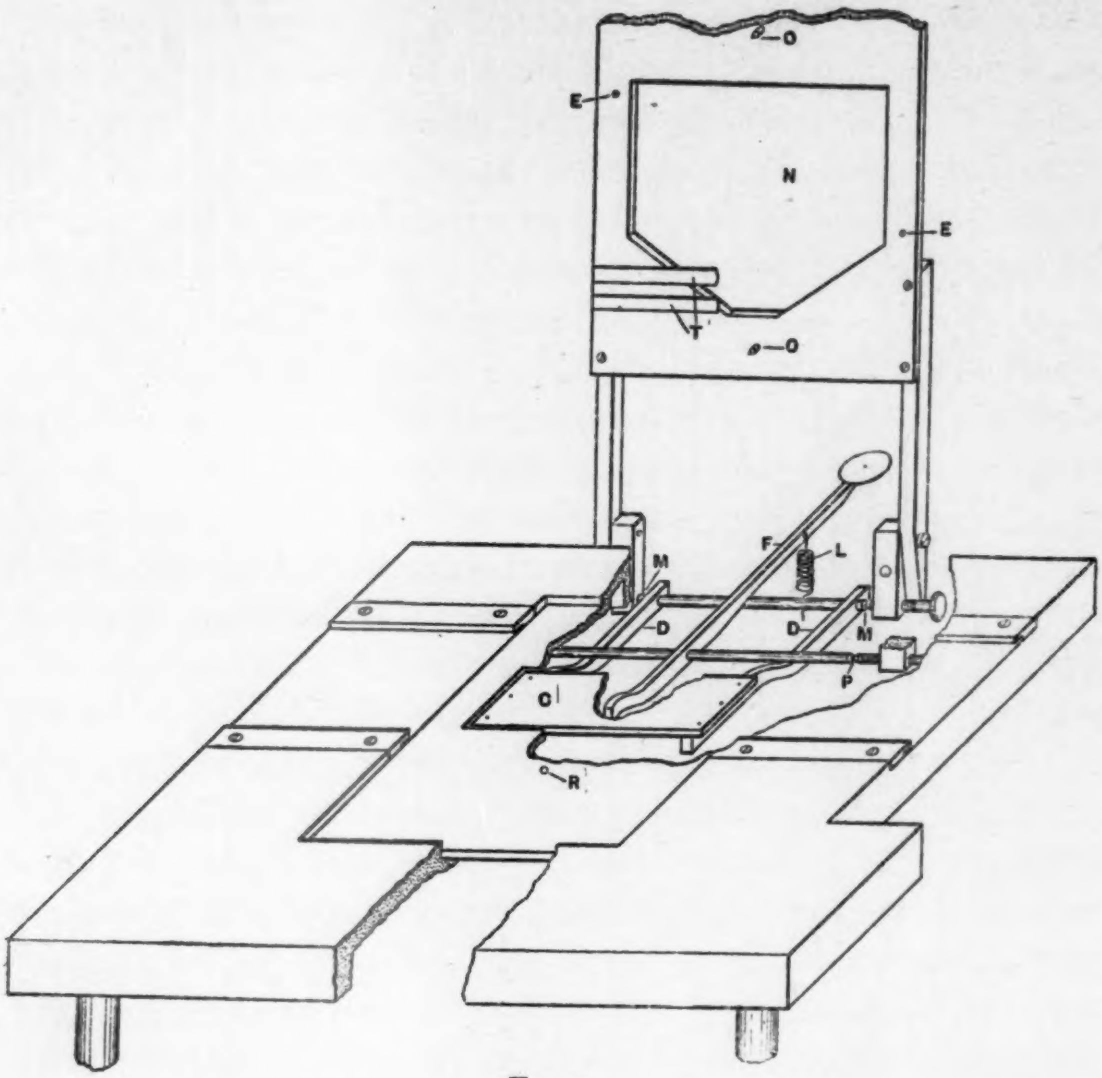


FIG. 2.

accuracy is obtained. In the second place, the apparatus gives a time record for the whole drawing or any part of it. As the subject draws upon the primary sheet his drawing is registered through the typewriter ribbon upon the moving strip. This gives a record of the whole drawing spread out under a standard time-line traced by the first marker. By correlating this with the original drawing in the manner described by Freeman, it is possible to follow the details of time changes throughout. In the third place, the apparatus gives a record of pressure. The drawings are made above the hinged plate which sinks slightly when pressure is exerted upon it. This movement of the plate, much magnified, is communicated to a pointer which traces a curve upon a smoked strip. In this way all changes in the pressure exerted by the subject in drawing are registered. This pressure

record is correlated with the records of time and accuracy through a second standard time-line traced upon the smoked strip by a second marker in circuit with the other. The time is given by a Kronecker Interrupter located in another room, marking tenths of a second. Three records are, therefore, obtained from each drawing movement, showing its accuracy, the rate of drawing throughout, and synchronous changes in pressure.

Several changes were, however, made in Freeman's apparatus. A finely-pointed lead-pencil was used in place of his capillary pen for the time-record on the moving strip. An electric motor was used to drive the apparatus. This motor was encased in a wooden box heavily lined with felt to shut in the noise. Its speed was reduced through a worm-gear mounted in a standard on the top of the box. The drum, C, Fig. 1, was turned by a string-belt from the driving-wheel of the worm-gear. This method lacks only one of the advantages of the original arrangement. It is not now possible to start the apparatus at full speed, as could be done when the friction clutch was used. This proved to be no detriment, however, as it took the apparatus only a very short time—about two seconds—to develop its maximum speed. This time was just about the interval the experimenter allowed between the starting of the motor and the giving of the signal to begin drawing. The chief advantage in using the motor is that it eliminates a great deal of distracting noise.

A third and more important change in the original apparatus was the substitution of a new pressure-recording device for the tambours. The tambours were used in the first practice series, and were found unsatisfactory for the purposes of this experiment. The pressure in a drawing movement is usually less in amount and more gradual in its changes than that in a writing movement. This calls for a recording device which is more sensitive and which magnifies the record to a greater degree. There is always a stretch to the rubber of the tambours and to the walls of the connecting-tube. The movements are thus softened down so that some of their characteristics are lost. The simple device used in these experiments does away with this deficiency, as well as satisfying the other conditions.

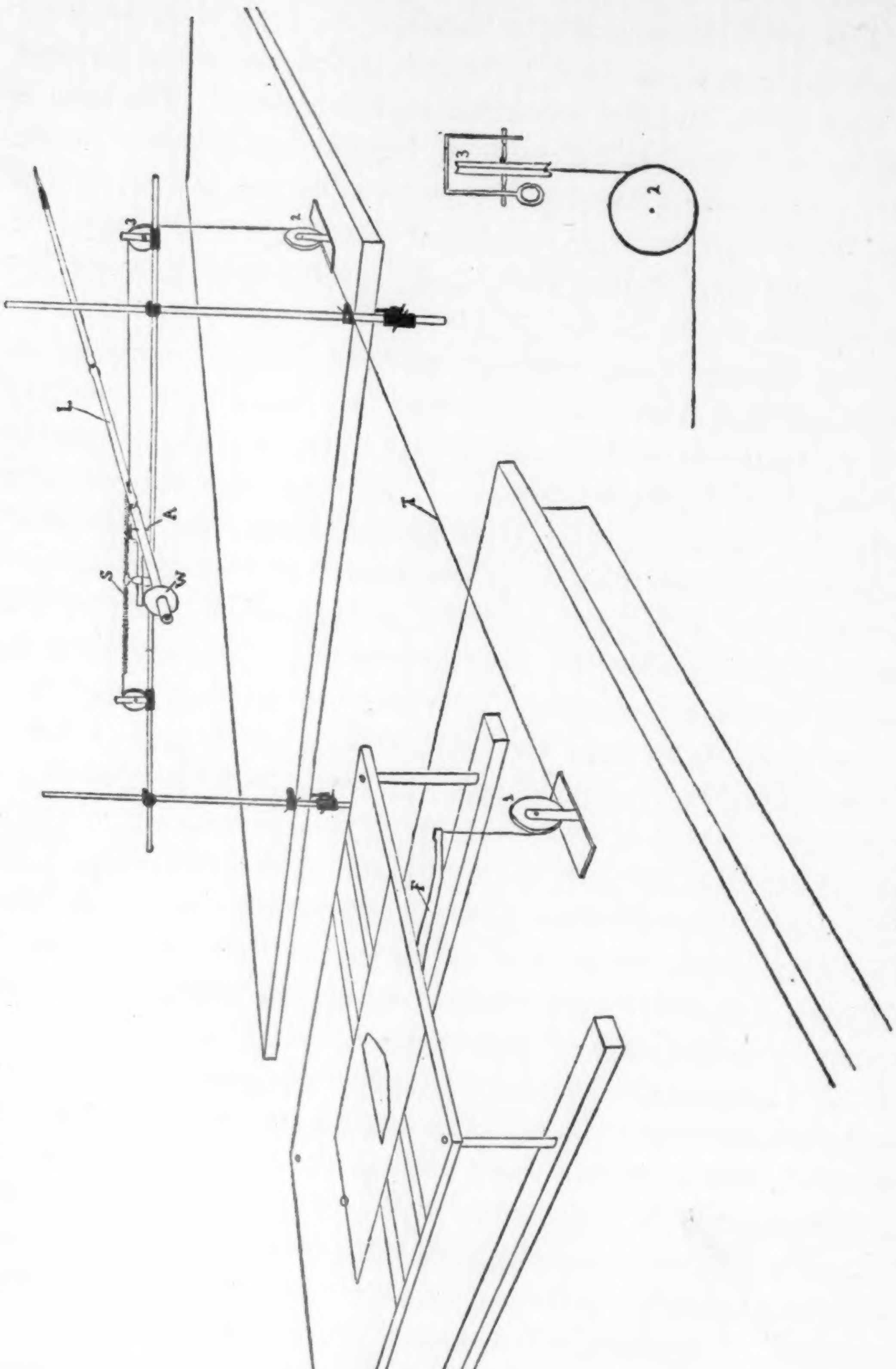


FIG. 3a.

FIG. 3.

The two tambours, I and K, Fig. 1, were removed, as was also the metal disc on the end of the lever, F, Fig. 2. A new recording-pointer was made. As this pointer was of considerable length, the drum D, Fig. 1, over which the smoked strip runs, had to be moved away from the rest of the apparatus. It was accordingly placed about a meter away from the drum, C, and run by a string-belt from a wheel on the axle of the drum C, to a wheel of the same size on its own axle. The marker, L, Fig. 1, was held by a special standard which stood on the table. The new recording-pointer was made of a thin piece of bamboo, L, Fig. 3, 60 cm. in length. At the recording end it was supplied with a metal recording-point. Near the other end it was pierced by an axis, A, which was then mounted in bearings. The movements of the lever, F, Fig. 2, were communicated to the recording-pointer by means of a thread running over a system of wheels. These wheels were made of wood and were supplied with fixed axles mounted on bearings, friction being thus reduced to a minimum. Fig. 3 shows how the movements of the lever, F, are communicated to the recording-pointer, L, which is at right angles to it and on a different level. The wheels over which the thread, T, runs are numbered 1, 2, and 3. An end view of the arrangement of wheels 2 and 3 is given in Fig. 3a. The thread was attached to the recording-pointer between the axis and the point—9 cm. from the axis and 42 cm. from the point. At this place too, on the other side of the pointer, there was attached a long fine spring, S, the tension of which could be readily and delicately regulated. A small round weight, W, Fig. 3, with a circular hole in the middle, was placed over the short end of the recording-pointer to make its weight equal on either side of the axis.

Another addition to the apparatus was the screen for cutting off the subject's view of his hand as he drew. The screen was of grey card-board, held in place by means of clamps, which were in turn held by uprights clamped to the large surface, A, Fig. 1. Another large screen of black card-board was used to cut off the subject's view of the pressure apparatus.

The marker, M, Fig. 1, used by Freeman to record the giving

of the signal in reaction experiments was not needed for our purposes, and was removed. A slight change was made in the arrangement of the marker, J. Instead of its being fastened to the plate, H, it was held just above it in a clamp attached to a rod running from one of the uprights holding the screen. To this same upright, higher up, were also attached the rod and clamp for holding the card on which the model was drawn. The models were drawn in black on white cards 12.5 cm. x 7.5 cm. The figures used are illustrated in Fig. 4, and will be described in detail in the statements of the individual series. The method of measurement adopted in each case will also be described there.

The apparatus was run more slowly than in Freeman's experiments, drawing movements being made more slowly and with more gradual changes in speed and pressure than writing movements. Moreover, the experiment is of such a character that it does not demand as minute an analysis of the movements as did Freeman's. Accordingly the apparatus was run just fast enough so that the records could be read in 100ths of a second.

In an investigation of this sort another requisite is that the subjects give full introspections. In our experiments they were instructed to tell after each experiment everything that had gone on in consciousness from the giving of the signal to begin the drawing to the end of the drawing. The introspective reports were not confined to this period, however, and general remarks made by the subject were also accepted by the experimenter though they were not given the same weight as the introspective report. Sometimes the experimenter increased the fulness of the report by appropriate questions, but care was taken that these should not be suggestive. Those who served as subjects were all trained psychologists. They were Professors Angier (A.) and Cameron (C.), Dr. E. P. Frost (F.), Instructor in Psychology, and Mr. S. L. Reed (R.), a graduate student in Psychology. To these men I am indebted not only for the large amount of time they have given me as subjects, but also for many pieces of helpful criticism and advice. The subjects were kept as naïve as possible. With the exception of A., none of them knew the purpose of the experiment, or anything about the results. A.

knew the purpose of the experiment, having himself suggested the problem, but he entered upon the investigation unconscious of any bias, and without anticipating any of the results. He was also kept in ignorance of his own results, though he did examine some of the results obtained from other subjects in cases where their task had been different from his own.

The method of procedure was as follows. Before each experiment the model was placed in its holder. The subject seated himself before the apparatus, took the pencil, and placed his hand under the screen ready to draw. He then received his instructions. The experimenter, after a preliminary "Ready" signal, started the motor and the two time-markers and, finally, gave the signal "Now" for the subject to begin drawing. This succession—"Ready," starting of apparatus, and "Now"—was not carried through in connection with any time-regulating mechanism, but the intervals were kept as nearly equal and constant as possible. As soon as the drawing was finished, the experimenter stopped the apparatus and took down the subject's introspections.

The instructions in these experiments, though not given in a stereotyped formula each time, were nevertheless definite and as brief as possible. At the beginning of a series the experimenter described to the subject in exact terms how the figure was to be drawn, i. e., that he was to begin at a certain definite point, proceed in a certain direction, and make his drawing as nearly like the model in size and form as he could. These instructions were briefly repeated for each drawing of the series. In all the earlier experiments no instructions were given concerning the rate of drawing or the pressure to be exerted, since variations in these objective factors, rate and pressure, were to be correlated with variations in introspective attitude, to give instructions about them would be to predetermine one of the variables. Later on, however, special instructions as to rate, and in a few cases as to pressure, were given in order to see if by purposely varying these objective factors a corresponding variation in attitude could be obtained, such as preceding experiments might have led one to expect would occur. When such special instructions were given they were always repeated in exactly the same words before each drawing.

At the start the subjects were told to report in their introspections all conscious processes that accompanied the drawing of the figures. No hint was given as to what processes were the object of the investigation, and all attitudes reported were given equal consideration. Early in the investigation, however, it was found, as had been to some extent anticipated, that the only attitudes that appeared universally enough to admit of systematic study and correlation were attitudes designated as "certainty" and "uncertainty." It was therefore to these attitudes that the experimenter directed his attention, and the variations introduced into the experiment were aimed directly at bringing them more clearly into the light. Moreover, the questions by which the experimenter enlarged the subject's introspective report often had to do directly with the attitude of certainty, although they did not reveal to the subject the fact that this attitude was the object of the investigation. The subjects still continued to report all the other attitudes, images and sensations they had experienced. It may be that other observers would distinguish other attitudes within the certainty and uncertainty experienced in a drawing process. However this may be, our subjects reported definite conscious attitudes, some of which were designated as attitudes of certainty and others as the opposite attitudes of uncertainty, and the contrast between them holds whether or not they might be called by other names or each divided into a number of different sub-classes. Certainty, however, may be of two kinds, as reported by our subjects. These are designated as positive certainty and negative certainty. Positive certainty is the attitude that the drawing made is correct. Negative certainty is the attitude that the drawing made is incorrect in some definite way. Uncertainty is the attitude that the subject can't tell whether the drawing approximates the model or not. The distinction between positive and negative certainty involves a distinction between the attitude of certainty and the accuracy with which the subject feels the drawing to have been made. The attitude of certainty might be that the drawing was accurate or it might be that it was inaccurate. In either case the attitude was certainty.

Certainty in a drawing may give way to uncertainty and vice

versa. Sometimes the attitude refers to one portion of the drawing, sometimes to the drawing as a whole. In the longer drawings there is reported a continuous attitude, which lasts throughout, varying between certainty and uncertainty. In shorter drawings the attitude may appear just as the subject finishes, and in such cases it usually refers to the drawing as a whole. There are, moreover, different grades to the attitude. At times certainty or uncertainty is more intense than at other times. These differences are reported by the subject in such terms as "good certainty," "only fair certainty," "a little uncertain," "typical uncertainty," "absolutely uncertain," etc.

In order to show a correlation between the attitudes reported and the objective records, it is evident that a fairly large number of experiments must be made, for the safety of this correlation depends upon the number of experiments and the taking of careful introspections. With the more complicated models that were used first in our experiments, twenty drawings were made of each model. With the simpler drawings, ten experiments were usually obtained for a series. In all about six hundred and fifty experiments were made.

We turn now to a consideration of the individual series of experiments.

Series I. Practice Experiments

The first experiments were conducted in the spring of 1912, chiefly for the purpose of finding out whether the apparatus and method were adequate. As already stated, these preliminary experiments showed that a new method of recording pressure would have to be devised and substituted for the tambours.

The drawing process in this series was the same for all subjects, the model being a single straight, vertical line, 27 mm. in length (Fig. 4, No. 1). The task was to draw three vertical lines, equal in length to the model line, parallel to each other, and equal distances apart. They were to be drawn from top to bottom, and the whole process to progress from left to right. At the close of the drawing the subject gave his introspections, and named the order of certainty of the lines he had drawn. He

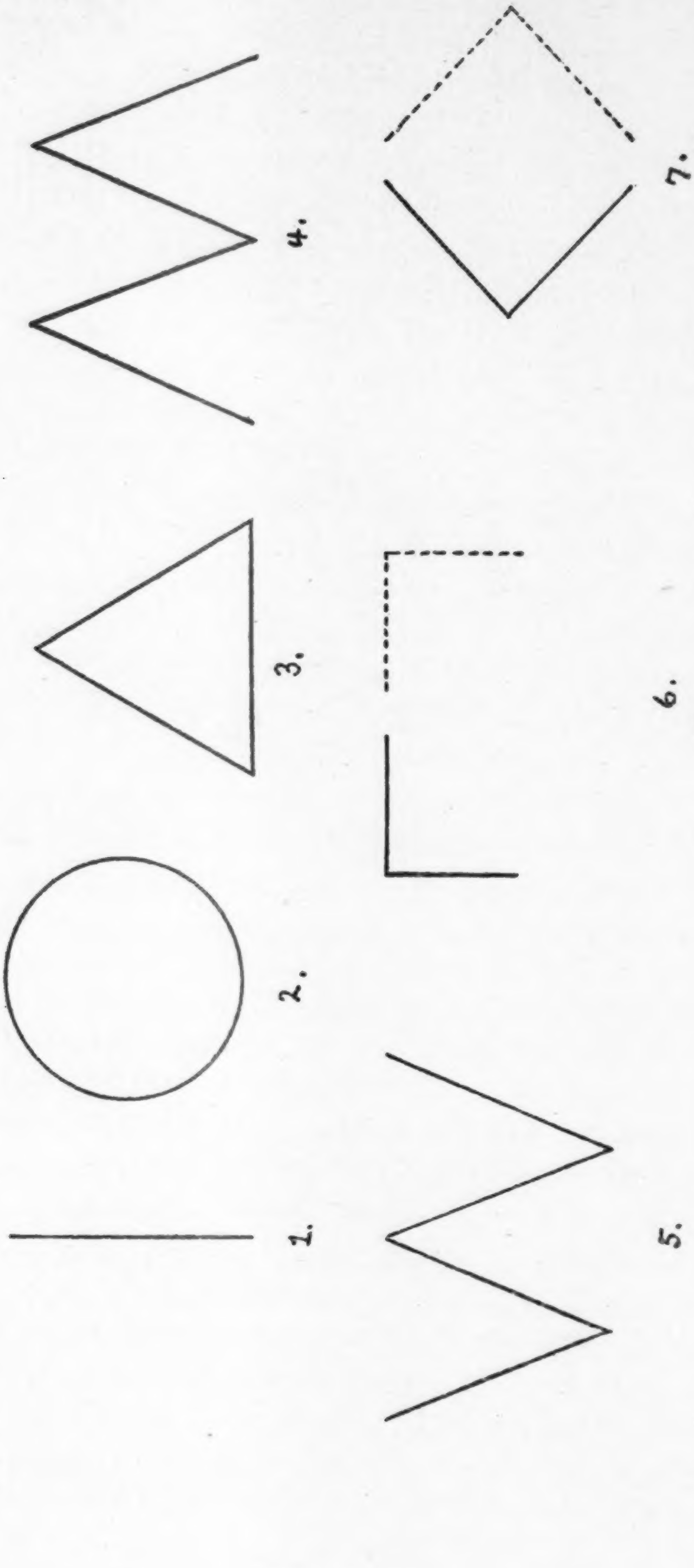


FIG. 4

ranked them from most certain to least certain. After a few experiments had been made, it was found that the first of the three drawn lines came to be regarded, without intention, as a sort of preliminary affair in which the subject simply "got the swing" of the process. The result was that he had little introspective knowledge of it, and it could not be compared with the other two lines. Since the introspective comparison of three lines was desired, this difficulty was obviated by having the subject draw four, the first of these to be a preliminary one to get the process started.

The lines in the drawing made by the subject were measured for accuracy as follows. *First,* their length was measured in millimeters. *Second,* an estimate of the straightness of each line was made. This was expressed in two ways. First the number of little waves or turns in direction was noted, and second the amount of deviation of the whole line from the vertical—determined with reference to a perpendicular to the horizontal boundary of the bottom of the space in which the subject drew. The distance from this perpendicular of the top of the line was measured and compared with a similar determination of the bottom of the line. Their difference, expressed in millimeters, gives the second measure of straightness. *Third,* the width of each interspace was calculated. This was done by taking the average distance apart of the two lines bounding it.

For purposes of time measurement the lines were divided into three equal parts and the time for each third calculated. In nearly every line, moreover, there were two periods, one at the beginning and another at the end, during which the pencil was touching the paper but not moving. The subject was not aware of the fact that he did not begin to draw the instant his pencil touched the paper, nor did he know that at the end of the line he held it still for a fraction of a second before raising it. The time for these two periods was also determined, making in all five time determinations for each line. Finally, the time between the end of each line and the beginning of the next, or the time in the interspaces, was also calculated.

These practice results are incomplete, the pressure records

being defective, and are hardly significant except as they point toward later results. The records of the lines which each subject called most certain, and those for his least certain lines were grouped together and averaged. In the cases of A. and R. the average most certain line is drawn at a slightly faster rate than the average least certain line. In the case of C. the opposite is true here, but later results do not bear this out. With F. it was impossible to compare the most certain and least certain lines, because of lack of complete introspection.

Certain differences in imagery between the individual subjects came out in the practice series, and, as they keep appearing throughout the whole investigation, it will be well to describe them here.

A.'s imagery is almost entirely visual. In starting a drawing he has a visual scheme of it to be filled in. This visual scheme is followed throughout, and any marked deviation from it is pictured in visual terms. Sometimes the visual scheme is weak and the imagery vague. In making a drawing without a model it seems important for this subject to keep his eyes fixated upon the cardboard screen in the general direction of his hand. In drawing from a model he keeps his eyes upon the card, but his tendency is, as he expresses it, "to use the model as a suggestion rather than as a plan," that is, to draw rather from his own visual image of the figure than from the figure itself.

C. reports chiefly kinaesthetic imagery and sensations in the drawing process. Any plan or scheme he has at the beginning of a drawing is in kinaesthetic terms. He sometimes prepares for a drawing by making incipient movements with the pencil. He is easily disturbed by any slight awkwardness in the manner of holding the pencil, or in the position of the hand. In drawing from a model he follows it with his eyes throughout. In drawing without a model he does not keep his eyes fixated in a particular way, but gets his hand placed carefully and then looks away. He reports visual imagery too, but his visual image always comes up after the drawing has been made, as the last stage of the process.

F. reports imagery of both types. The most prominent kind

of imagery with him is visual-motor. He images the developing figure as he draws, and he often visualizes the moving pencil-point as well.

R. reports less imagery than any of the other subjects. What he does report is chiefly visual, with occasional kinaesthetic, imagery. Often incomplete visual images appear. Part of a line will be visualized and the rest will not appear. Sometimes a line will be visualized as heavy and dark at one end, but gradually shading off into nothing at all at the other end.

Series II, IIa and IIb

The remainder of the experiments were made in the fall of 1912, and the winter and spring of 1912-13. In the present series each subject was given a different figure to draw, and so a different task. Series IIa is in each case a variation upon Series II. In treating these series we will take up the different subjects separately.

Subject A.—A. was given as a model a circle, 27 mm. in diameter (Fig. 4, No. 2). He was instructed simply to copy the circle exactly, beginning at the top and drawing in the anti-clockwise direction, using a finger movement and not shifting the position of his hand during the drawing. The anti-clockwise direction was chosen because it seemed to the subject that it would be more natural for him than the clockwise direction. After taking a series of twenty such anti-clockwise drawings a variation was introduced by having the subject draw the circle in the opposite direction, still beginning at the top. A series of twenty such clockwise drawings was also obtained, forming Series IIa. Then, after a long interval (October to April), during which a large number of other experiments had intervened, another series of ten anti-clockwise drawings was made. These form Series IIb.

The method of measurement for these drawings was as follows. For accuracy, the approximate center of the circle drawn by the subject was found with a compass. Then four axes were drawn through it, the vertical, the horizontal, and the two diagonal axes. When compared with the diameter of the original

circle, the lengths of these axes give a good estimate of the accuracy of the circle as to size. When compared with each other they give a good measure of the roundness of the circle. In measuring the accuracy of the circle, also, the distance from end to end, that is, the amount by which the end point failed to meet the starting-point, was measured in millimeters. This measurement is expressed as the "distance from end to end" under the abbreviation "E. to E."

For measuring time changes during the process of drawing, the circumference was divided into quarters. A more minute division of the circumference seemed unnecessary because of the character of the subject's introspections. These were nearly always given in terms of halves or quarters of the circle, the subject making these divisions guiding marks in his description of the course of mental processes during the drawing. It was therefore evident that any changes in drawing rate which could be correlated with a change of attitude should show in a comparison of the quarters. The end-points of the vertical and horizontal axes were taken as marking the boundaries of the quarters of the circumference. This, of course, is not absolutely accurate, as the drawn circle was never perfectly round, but it is exact enough for our purpose. The pressure record was also divided into four quarters.

For brevity and convenience in exposition, the results of these series will be treated as a whole by a consideration of the averaged measurements of the twenty drawings and a summary of the introspection. The individual drawings show such uniformity in their characteristics that this may be done.

The introspections for both Series II and IIa show that a continuous attitude accompanied the drawing of the circle from start to finish. The anti-clockwise circles are more certain than the clockwise. This is shown both in the relative number of attitudes of certainty reported, and in the general remarks of the subject. In both types (clockwise and anti-clockwise) the drawing of the second half is accompanied by less certainty than the first. In Series II, the anti-clockwise circle, a point of maximum uncertainty is sometimes located, and when it is thus mentioned,

as it is in six of the experiments, it is always located as either in the third quarter of the circle or between the third and fourth quarters, at the place where the figure III appears on a clock-face. In Series IIa (clockwise) a point of maximum uncertainty is sometimes mentioned; but it does not show any uniformity in the place at which it occurs, except that it is usually somewhere in the second half of the drawing.

The accuracy and time measurements for Series II and IIa are compared in Table I.

TABLE I

Subject A

	Axes				Time, in seconds				
	II		IIa			II		IIa	
No.	Lgth.	M.V.	Lgth.	M.V.	Quarter		M.V.		M.V.
1.	21.8	2.35	21.1	2.01	1st	2.91	.62	3.39	.58
2.	24.	2.35	21.5	2.72	2d	2.45	.40	2.73	.31
3.	23.8	2.69	21.5	2.87	3d	1.54	.30	2.57	.40
4.	21.6	3.12	21.9	2.25	4th	3.26	.43	2.91	.45
Ave.	22.8		21.5		Total	10.16	1.41	11.60	1.07
E. to E.			II.	6.	IIa. 3.7				

It will be seen from this table that the circles are very nearly the same size. Their average diameters differ by only 1.3 mm. They differ, however, in shape, the anti-clockwise circle being slightly elongated along its first diagonal axis. The clockwise circle shows less difference in the lengths of its axes, and is more nearly round. The distance from end to end is less too. Thus, the anti-clockwise circle is a little more accurate than the other in size, while the clockwise one is slightly more accurate in shape. So the less certain circle is a little less accurate than the other in size, but more accurate in shape.

We turn now to the consideration of the time records. It will be seen from the table that the four quarters of the circle vary a great deal from each other in the speed with which they are drawn. In the anti-clockwise circle the drawing begins slowly in the first quarter, becomes somewhat faster in the second, is fastest in the third, and then in the fourth is slower than ever before. Thus the maximum change of speed comes between the third and fourth quarters, and the change is a retardation. In the other circle we find smaller differences between the times

of the respective quarters. The third quarter is again the fastest, but the difference between it and the fourth is not as great. Instead, the greatest difference is between the first and second quarters, but this too is smaller than that between the third and fourth quarters of the other circle. There the difference was 1.72 sec., here it is only .66 sec. Moreover, the change in the first case is a decrease, here it is an increase in speed. In connection with these characteristics of the time records it will be remembered that in the anti-clockwise circle the point of maximum uncertainty, when it was located, came in the third quarter or between the third and fourth. Also, that while less certain as a whole than the anti-clockwise circle, the clockwise one does not show any definite point of maximum uncertainty. Thus, in so far as we have been able to locate a point of maximum uncertainty, that point comes at the place where the greatest change in speed is taking place, and that change is a decrease. In general the clockwise circle is less certain than the anti-clockwise one, and the table shows that it is drawn more slowly. The second half of each type of circle is less certain than the first, and the table shows that in each case the first half is drawn at an increasing, the second half at a decreasing rate. The point of maximum uncertainty comes in the anti-clockwise circles at the point where the figure III is located on a clock-face. This is the same point with reference to the hand as the end of the first quarter in the clockwise circle. In the first case uncertainty is reported, in the second certainty. In the first case there is a greater change in rate and it is a decrease, whereas in the second case the change is smaller and it is an increase.

The pressure records show certain similar characteristics that hold throughout. In the records for both circles there is a gradual increase of pressure at the beginning, which lasts as a rule throughout the first half, and sometimes as far as the middle of the third quarter. When the third quarter is reached there is usually a decrease in the pressure curve of the anti-clockwise circle. This decrease appears in fourteen of the twenty drawings of Series II. In two drawings it does not appear, and in the remaining four the records are defective. This decrease in pres-

sure comes at the same part of the circle as the great decrease in rate revealed by the time records. It is also at the place at which the maximum uncertainty is reported when it is reported at all. In the two cases where there is no decrease in the third quarter the introspections show that the circles are unusually certain ones. Thus, the decrease in rate and pressure between the third and fourth quarters seems connected with the appearance of uncertainty. In Fig. 5, No. 1, we have a tracing of a curve of this sort from Series II. This curve is reduced in its length but not in its height. The differences in the height of the original curve are so slight compared with its great length that they would not show well if the reduction were made proportional throughout. All the tracings in this article, however, except those in Fig. 5 and two in Fig. 6, are made proportional throughout. Reducing is done by means of a pantagraph. In all the curves a rise indicates an increase in pressure.

The pressure curves of Series IIa, the clockwise circles, show much the same characteristics as the others in their first halves. There are, however, a somewhat larger number of changes in pressure. The second half, in six cases out of the twenty, shows a decrease between the third and fourth quarters. In three of these cases it is accompanied by an attitude of uncertainty. In Fig. 5, No. 2, is given a typical pressure curve for a clockwise drawing. It shows in its first half the same general characteristics as the curve for the other circle, but it has not the decrease between the third and fourth quarters. In Fig. 5, No. 3, we have one of the clock-wise circles which differed from the others of the series markedly. The subject said in his introspections on this circle that he started not with the intention of following the model around as he drew, but rather to draw the circle in one quick sweep. The time records show that this circle was drawn nearly twice as fast as the average, and there is less slowing up in the second half. The result was that the changes in attitude were reduced in degree. The difference in certainty between the first and second halves was less markd. The curve shows scarcely any difference from beginning to end. So we find that in this experiment where the typical difference in certainty is reduced,

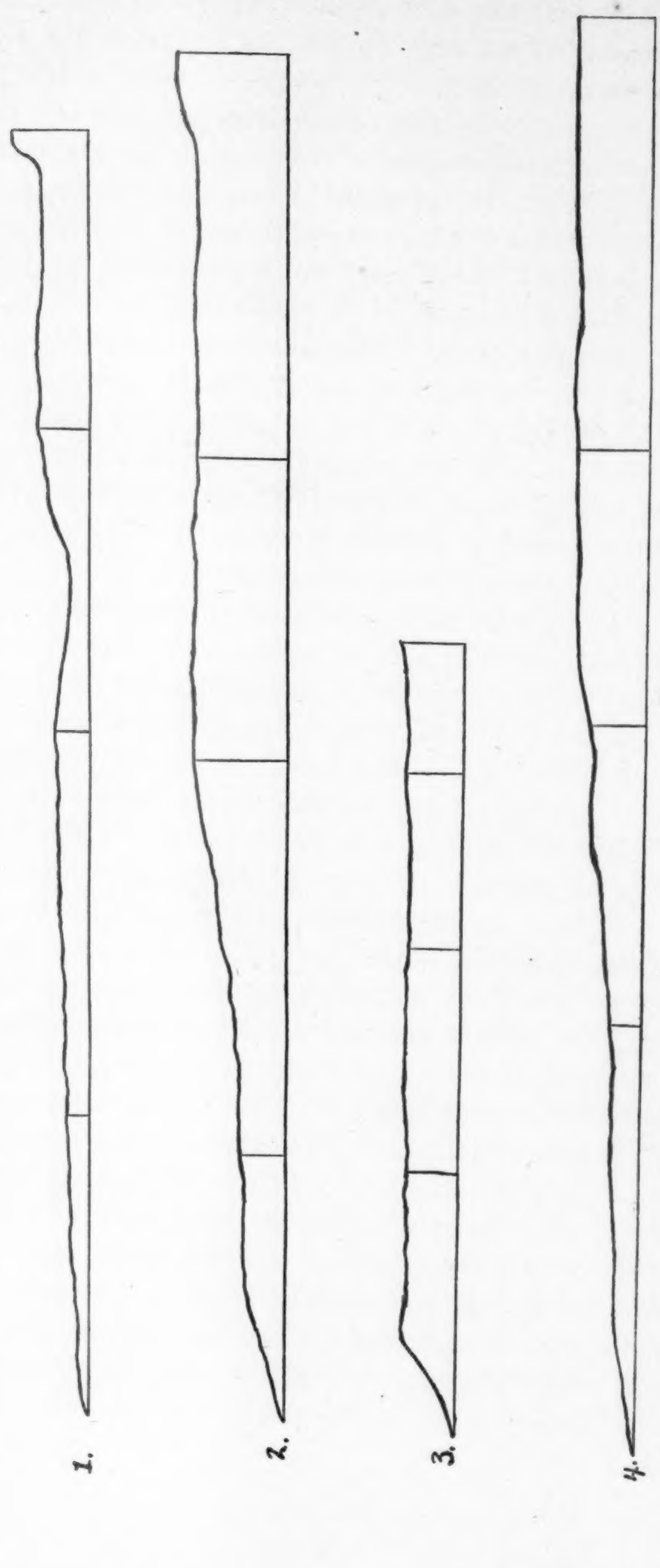


Fig. 5.

the difference in the character of the pressure curve for the two halves is also reduced.

Summing up the results for Series II and IIa, we find that:—

(1) The anti-clockwise circle, which the subject said at the start would be more natural for him, is found in general to be drawn with more certainty than the other one. The first half of each circle is more certain than the second half.

(2) The anti-clockwise circle is more accurate in size, but less accurate in form than the clockwise one.

(3) The clockwise circle is drawn at a slower rate than the anti-clockwise one. In each circle the first half is drawn at an increasing rate and the second half at a decreasing rate.

(4) The pressure curves for the two circles are similar in that there is a gradual rise throughout the first half. The second halves of both curves differ from the first halves. In the anti-clockwise drawings there is a decrease of pressure between the third and fourth quarters. In the clockwise ones this decrease sometimes appears, but there is no regularity about it.

(5) Attitudes of uncertainty go with the second halves of the circles, and especially with the middle of the second half of the anti-clockwise one. At these points there is a decrease in the rate of drawing, and, in the anti-clockwise circle, a decrease in pressure.

At the end of all the experiments a series of ten anti-clockwise circles was made, Series IIb. The results of this series appear in Table II, which follows the plan of Table 1.

Table II Subject A

Axes			Time		
No.	Lgth.	M.V.	Quarter		M.V.
1.	14.4	1.2	1st	3.88	.51
2.	15.1	1.1	2nd	2.89	.45
3.	14.5	1.2	3rd	2.12	.26
4.	14.4	1.2	4th	3.30	.38
Ave.	14.6		Total	12.19	1.12

This table shows that the circle is now drawn more accurately as far as its shape is concerned, but it is made much too small. The subject gave no indication in the introspections that he was aware of the small size of his drawing. This variation was intro-

duced primarily to see if there would be any indication of practice effect in the results, and what the effect of this would be upon the attitudes reported. The subject noted some indication of practice effect. This did not appear immediately, but was reported first in the fifth drawing of the series.

In general the drawings of this series are more certain than those of Series II. The subject is able to tell more clearly just what he has done, he reports more attitudes of both positive and negative certainty, and fewer attitudes of uncertainty. There is no longer a specific place at which the maximum uncertainty appears. It is noted only once, and there it is in the fourth quarter. An examination of the time records shows that the drawings as a whole are now made more slowly than in the other series, and there is less difference in time between the third and fourth quarters.

The pressure records of this series are not very satisfactory, owing to the very slight pressure with which the subject drew. Four of the ten are not good enough to give results. In the other six the pressure is fairly constant in its increase from beginning to end, or else it increases quickly at the beginning and maintains about the same level to the end. There is never a decrease between the beginning and the end. One particularly certain drawing was obtained—one in which no uncertainty is reported anywhere in the course of it. The pressure curve for this drawing is illustrated in Fig. 5, No. 4. It will be observed that it rises gradually throughout, with no marked changes, and never a decrease.

In this series, therefore, we find that with the greater certainty revealed in the introspections there is a change in the time and pressure characteristics, this change being in the direction which we have already found to tend toward certainty. The circle as a whole, however, is drawn more slowly than before. Previous results have seemed to indicate that certainty goes with a fast rate of drawing. Thus it would seem that in a long drawing of this character the rate of the total drawing is less important for the attitude than relative rates of the different parts.

Subject C.—With C., the model in Series II and IIa consisted of an equilateral triangle, the sides of which were 28 mm. in

length. This is No. 3 in Fig. 4. In Series II the subject was instructed to draw the triangle beginning at the apex, then drawing obliquely downward to the left, then horizontally to the right, and then obliquely upward to the left to the apex again. Twenty drawings were made in this way. In Series IIa the subject began to draw the triangle at the lower left-hand corner, going first along the horizontal line to the right, then obliquely upward to the apex, and obliquely downward to the starting-point again.

This figure proved to be the least satisfactory of all those used. The drawing of it is not really a continuous process like the drawing of the circle, because the subject pauses at the corners. On the other hand, the three lines are not repetitions of the same mechanical process, as are the three vertical lines of the practice series. That these characteristics are unfavorable to the appearance of contrasts in attitude which can be reported, is shown by the character of the introspections. There was no continuous, changing attitude as in the case of the circle. On the other hand, the lines of the triangle were not compared with each other as were the lines of the practice series. Thus, different parts of the same figure cannot be compared, and the only comparison the introspections allow is of one whole figure with another, or a certain part of a whole figure with a similar part of another.

The method of measurement was to measure the lines and angles of the drawn triangle and the amount by which the end failed to meet the beginning. The lines are numbered 1, 2, and 3 in the order drawn in each case. The angles are similarly numbered.

Table III gives the accuracy and time records for Series II and IIa. The average of twenty drawings is given in each case. The length of the lines is given in millimeters, as is also the distance E. to E. The angles are given in degrees.

TABLE III Subject C.

			II			
No.	Lgth.	M.V.	Angles.	M.V.	Time	M.V.
1.	25.4	3.7	55.8	1.8	2.30	.57
2.	36.4	5.9	70.9	3.9	2.67	.63
3.	30.4	3.3	57.2	2.6	2.14	.91
	E. to E. 16.5				Total 7.11	1.39

IIa

No.	Lgth.	M.V.	Angles.	M.V.	Time	M.V.
1.	43.8	5.1	79.9	3.8	5.40	1.46
2.	34.7	5.9	47.	4.7	4.73	1.69
3.	40.3	3.3	50.3	4.5	4.90	1.57
	E. to E. 14.5			Total 15.03		4.66

The large mean variations shown in this table indicate that there was very little uniformity in the drawing in either series, especially in the time. This makes it impossible to draw any conclusions, and owing to the difficulty of getting definite introspective comparisons between well-defined parts of these drawings, it is not possible to derive much of value from the pressure records. The only possible correlation between certainty and pressure in Series II is a very broad one. Of the fourteen cases in which drawings had been designated as certain as a whole or uncertain as a whole, five were called certain and nine uncertain. As a whole the pressure curves of the certain drawings are more smooth and even than those of the uncertain drawings. The changes in pressure are more gradual and less frequent in the certain drawings than in the others. The difference between the certain and uncertain curves is not very great to be sure, but it holds in all but two cases out of the fourteen. Fig. 6 gives in No. 1 a tracing of a typical curve for a certain drawing, and in No. 2 one for an uncertain drawing. These curves, as in the case of the circles, are so long that a reduction of their height in proportion to the reduction of their length would make the changes in height very small. They are therefore reduced more in length than in height.

In Series IIa no such comparison of whole drawings is possible as the subject there gives detailed introspections of the process, but does not give an indication of an attitude toward the figure as a whole. There is, however, one very marked peculiarity which appears in some of the pressure curves. This is a sort of "plateau" at the end. It will be remembered that in this figure the end comes at the lower left-hand corner, and the last line is the downward diagonal from upper right to lower left. At the end of this line and completing the figure, this plateau occurs in eight out of the twenty cases, being absent in the other twelve.

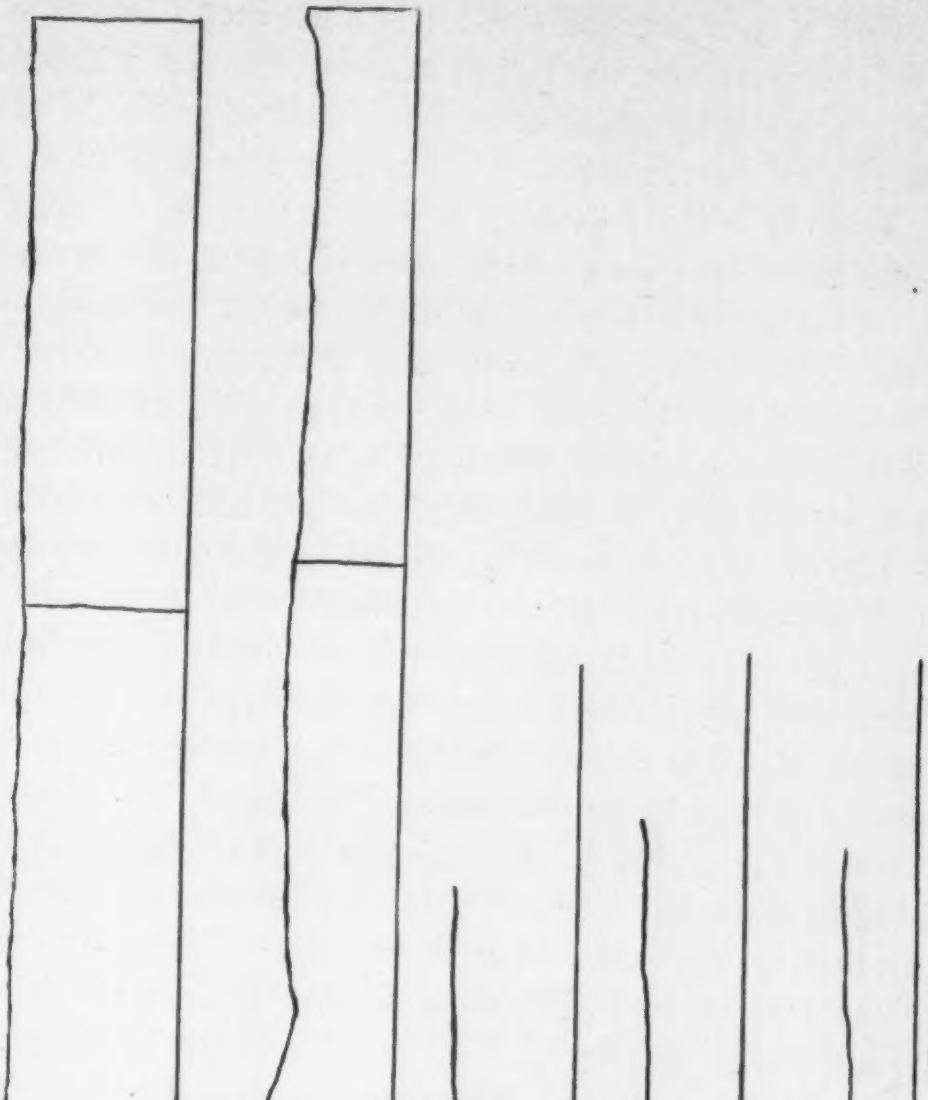


Fig. 6.

In Fig. 6, No. 3, a marked plateau is illustrated. No. 4 is an ending of the same sort, but not as marked, and No. 5 illustrates the end of a curve in which there is no plateau. The reduction of these is uniform throughout. The introspections show that in each drawing where a plateau appears at the end of the pressure curve there was an attitude of certainty at the instant of ending. This attitude appears in all but two of the eight cases where the curve shows a plateau, and it appears in only three of the other twelve drawings of the series. This attitude often gives way immediately to a reflective attitude of uncertainty toward the process as a whole, and this attitude of uncertainty seems closely bound up with the visual image which comes up just after the completion of the drawing.

Subject F.—The model used with F. in Series II consisted of four slant lines, 27 mm. in length, put together somewhat in the form of an M. For Series IIa the model was the same figure inverted. The first figure is illustrated in Fig. 4, No. 4, and the second one in Fig. 4, No. 5. In both these figures the subject was instructed to draw the lines all from top to bottom, this being the way that seemed most natural for him. There are certain similarities and certain differences in the process of drawing these two types of figures. Lines 1 and 3 of the first type correspond to lines 2 and 4 of the second in that they are drawn from upper right to lower left, and are parallel to each other. Similarly, lines 2 and 4 of the first figure correspond to lines 1 and 3 of the second in that they are drawn in the other oblique direction and form a parallel pair. The lines of both figures are the same in that they are drawn from top to bottom in each case and are slanted at the same angle from the perpendicular. An important difference between the two figures is that in the first the subject is drawing down *from* points, while in the other he is drawing down *to* points. There is a difference in the mechanical difficulty of drawing a line from upper right to lower left and in the other oblique direction. The former direction the subject pronounced the easier, mentioning it several times in the course of the series.

The method of measurement was as follows. First, the length

of each line was measured in millimeters. Then the straightness of the line was indicated by a figure expressing the number of slight deviations that occurred in it. The direction of the line was determined and expressed in terms of the number of millimeters by which the line deviated from the correct slant. Finally, the amount by which the successive lines failed to meet each other at the points was also determined in millimeters.

For time measurement the four lines were divided into halves. The time was determined in each line, first for the period at the start during which the pencil was down but not moving, then for each of the two halves, and then for the period at the end during which the pencil was at rest. The time elapsing between the end of one line and the beginning of the next, or the time in the points, was also determined.

Table IV gives the accuracy averages for the twenty drawings

TABLE IV

Subject F.

II				
No.	Lgth.	Str.	Dir.	Points
1.	30.9	1.1	1.6	5.72
2.	23.9	1.7	1.3	4.75
3.	26.5	1.2	3.2	3.25
4.	21.7	2.1	1.3	

IIa				
No.	Lgth.	Str.	Dir.	Points.
1.	29.0	2.0	4.3	4.05
2.	26.3	1.6	2.3	3.22
3.	22.6	1.5	2.5	4.45
4.	28.1	1.9	2.3	

of each series. It will be seen from this table that in Series II, lines 1 and 3 are more accurate, except in direction, than 2 and 4, while in Series IIa just the opposite is the case. So, the lines which are mechanically easiest to draw are those which are drawn most accurately. There is a certain correspondence between parallel pairs in the same figure, and in each series line 1 is drawn longer than any of the others.

The time records for Series II and IIa are given in Table V—in each case the average of twenty experiments. The smaller time determinations—those for the parts of the lines—do not

show any marked uniformities and are omitted from this table. Under "Time" is given the average time for each line. Under "Rate" is given the average rate at which it is drawn. The rate is determined by dividing the length of each line by the time it took to draw it. This gives the rate in millimeters per second, and the average of these determinations appears in the table. Under "T. P." is given the average time between the ending of one line and the beginning of the next.

Of the columns in this table those for rate are the most important. In II the rate for line 1 is higher—a greater number of millimeters per second—than that of any of the other lines. As a pair too, 1 and 3 are more rapidly drawn than 2 and 4, just

TABLE V

Subject F.

II

No.	Time	M.V.	Rate	M.V.	T.P.
1.	4.27	.38	7.40	.96	.92
2.	4.32	.37	5.67	.87	1.08
3.	4.10	.46	6.47	1.03	.82
4.	4.44	.43	4.85	.57	

IIa

No.	Time	M.V.	Rate	M.V.	T.P.
1.	4.36	.33	6.69	.65	.84
2.	3.69	.36	7.05	.77	.86
3.	3.86	.33	5.92	.56	.89
4.	3.68	.31	7.67	.92	

as in the accuracy table they are found to be drawn longer. In Series IIa we find that 2 and 4 are more rapidly drawn than 1 and 3, though 1 is drawn fairly fast. The accuracy table shows that these fast-drawn lines are long, so that in general the tendency to draw at a fast rate and the tendency to make the line long go together.

From the introspections it is possible to get in a general way the order of certainty of the four lines in Series II and Series IIa. There is sometimes enough difference between the four lines introspectively to enable the subject to name them in their order of certainty. Where this is not given it is often possible to tell from the general character of the introspective report what this order

was. The order of certainty most frequently given in Series II was 1, 3, 2, 4. This order was given five times. The order of certainty is given in all only nine times, and no other order of certainty appears more than once. This order receives support also from the introspections in which the certainty of one or two lines is spoken of, but the complete order not given. Line 1 is called most certain in every case, line 4 is called less certain than line 2 in all but two cases. The general outcome of the introspections of Series II, as far as the order of certainty is concerned, is that line 1 is the most certain line, that 1 and 3 are more certain than 2 and 4, and that the most usual order of certainty is 1, 3, 2, 4.

Recurring for a moment to the accuracy and time records, we find that the most certain line 1 is the longest and most rapidly drawn. Line 3 is next in length and rapidity, and then follow lines 2 and 4 respectively.

The introspections of Series IIa are somewhat more definite than those of Series II. Line 1 is again most certain in all but two of the twelve cases in which the order of certainty is given. Lines 2 and 4 are much more certain in this series than in the other one, and line 3 is called least certain every time it is compared with the others. The typical order of certainty for this series is 1, 4, 2, 3.

Turning to the records of accuracy and time for this series, we find that the certainty of line 1 and of lines 2 and 4 goes with greater length of line and faster rate of drawing. The greater length and faster rate of line 1 is, however, not as marked here as in the other figure where it is drawn in the other easier oblique direction. Lines 2 and 4, which are more certain in this figure than in the other one, are also drawn at a faster rate here than they were there. Line 3, which is least certain in this series, is drawn most slowly and is shortest. So it tends to hold here too that certainty goes with a long line rapidly drawn.

One other point must be considered before we go on to the pressure records. It was emphasized above that lines drawn from upper right to lower left were mechanically easier for the subject to execute than the lines drawn in the other oblique

direction. Does certainty simply go with this mechanical ease of drawing? In Series II it evidently does. Lines 1 and 3 are more certain than the mechanically harder lines 2 and 4. If it is true of the other series as well, lines 2 and 4 should be more certain than lines 1 and 3. We find that they are more certain than 3, but not as certain as 1. If we should try to show a correlation between certainty and the mechanical ease of drawing, we would be unable to explain how line 1, mechanically easy in one case and mechanically difficult in another, is yet most certain in each case. The fact that it is the first line drawn in each case doubtless has something to do with it, but this will not help our explanation unless the fact that it is the first line drawn makes the process of drawing it characteristic in some way that will show in our records. In the cases of the other lines we have found a correlation of certainty with length of line and fast rate. This does not hold in the case of line 1 in Series IIa in comparison with lines 2 and 4 of its own series, for although it is longer and drawn at a faster rate than the other three lines which are drawn in the same direction (II, 2 and 4, IIa, 3) it is not drawn faster than, nor is it much longer than, lines 2 and 4 of its own series. Its certainty must therefore be connected with some other factor which we have not yet observed.

We find such a factor the moment we examine the pressure curves. The pressure curves for line 1 conform to the same type throughout both series, except two cases in Series IIa where alone line 1 is called uncertain. The form of the curve is a gradual steady rise to a maximum which is held without decrease to the end. Fig. 7 shows two curves (Nos. 1 and 2) for line 1, the first from Series II, the second from Series IIa. No. 3 is a curve from one of the two drawings in Series IIa in which line 1 was called uncertain. Its variation in form is marked. We find here, therefore, in line 1, that certainty and a definite type of curve go together, and that this holds regardless of the mechanical ease or difficulty with which the line is drawn.

In the later lines of the drawings the curves show greater pressure than in line 1, and a somewhat different shape. They rise more quickly and their increase is not quite as uniform. Fig. 7,

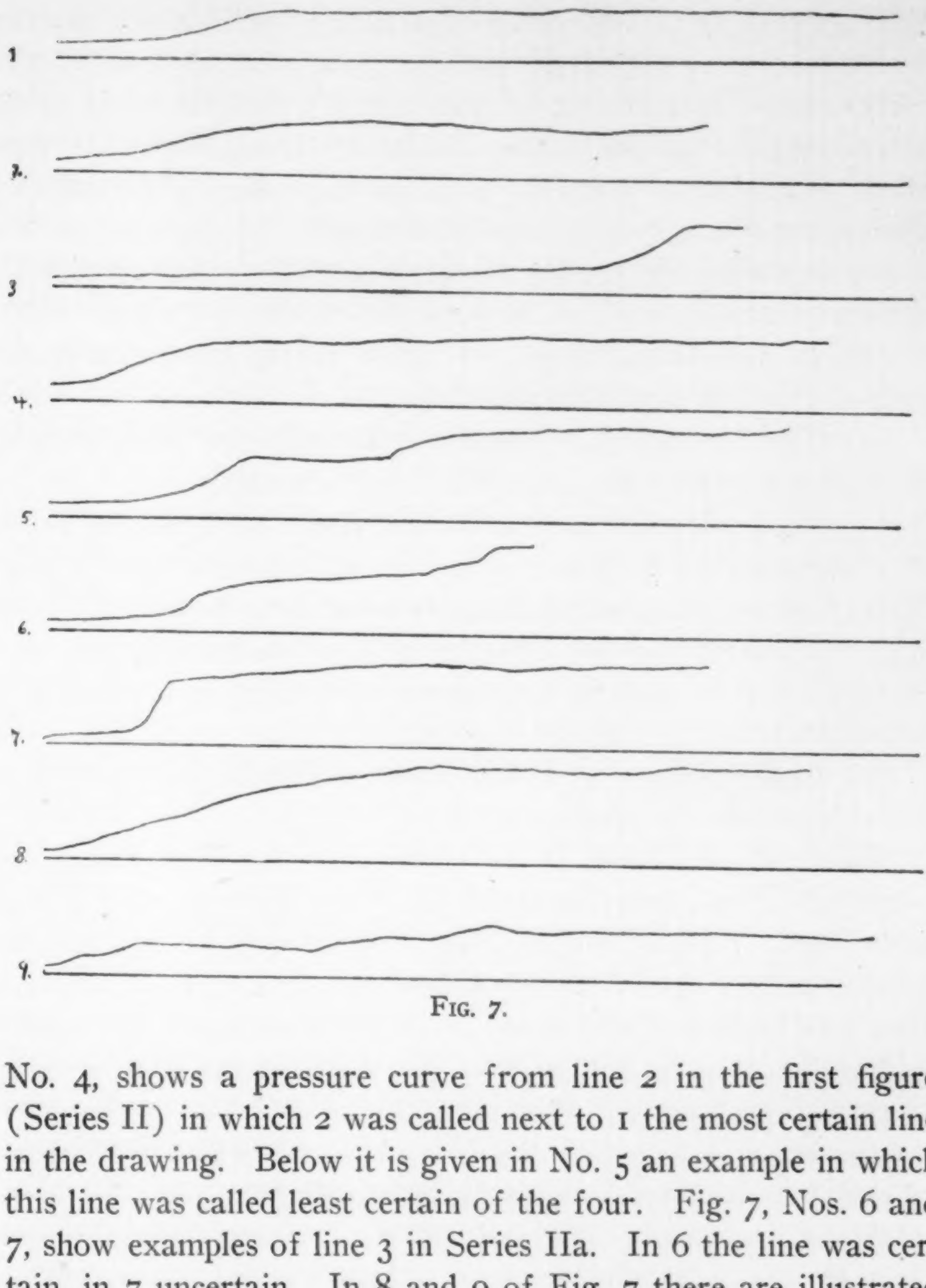


FIG. 7.

No. 4, shows a pressure curve from line 2 in the first figure (Series II) in which 2 was called next to 1 the most certain line in the drawing. Below it is given in No. 5 an example in which this line was called least certain of the four. Fig. 7, Nos. 6 and 7, show examples of line 3 in Series IIa. In 6 the line was certain, in 7 uncertain. In 8 and 9 of Fig. 7 there are illustrated two pressure curves of line 4 in the first figure (Series II). In No. 8 line 4 was certain, in No. 9 it was uncertain.

This correlation between certainty and a definite type of curve, and uncertainty and a variation from that type holds in every case for line 1 in both figures. It also holds where a line, usually certain, is pronounced particularly uncertain. But it does not

hold between small differences in certainty. There are examples in the records of both figures where there is no appreciable difference between the curves of lines 2 and 3, and yet one is called more certain than the other. Evidently, then, only wide contrasts in subjective certainty show corresponding differences in the pressure records under the conditions of this experiment.

Summarizing the results of this experiment with subject F. we find that:—

(1) In general certainty goes with a longer line and a faster rate of drawing than does uncertainty.

(2) The lines which are mechanically easy for the subject to execute are usually the lines drawn in this way.

(3) Line 1 is most certain in each figure, though in the first it is mechanically easy and in the second mechanically difficult. This certainty is correlated with a definite form of pressure curve which is followed in the drawing of line 1 in both figures, and is departed from only in the two cases in which line 1 is called uncertain.

(4) In the other lines marked contrasts in subjective certainty are reflected in the pressure curves.

Subject R.—In Series II the experiment with R. was identical with that of the practice series after the preliminary line had been added to the other three. It consisted in drawing the four parallel vertical lines from top to bottom. In Series IIa a variation was introduced. This was simply that instead of being drawn from top to bottom the lines were drawn from bottom to top.

One change was made in the method of measurement. Instead of dividing the lines into thirds and finding the time for each third, the lines were divided into halves. Twenty drawings were made in each series, and the usual full introspections were taken. The subject was able in almost every case to name the lines in their order of certainty. No uniform order of certainty developed. The succession of drawing, or the position of a line in a drawing had no effect upon its certainty or uncertainty.

A comparison of the accuracy and time averages of Series II and Series IIa shows that the lines when drawn from bottom to

top (IIa) are longer, less straight (though as good in general direction), and more slowly drawn, than the lines of the other series where they are drawn from top to bottom. These differences cannot be correlated with a general difference in certainty between the two sets of lines. The introspections reveal no general difference which would enable us to say that one series had been more or less certain than the other. Yet, since the two series show such marked differences in the accuracy and time records, we must keep the two series separate when we compare the records of the most certain lines with those of the least certain ones, as we now proceed to do.

The averages of the most certain lines and least certain lines are given in Table VI. The smaller time determinations are omitted as they show no differences between the most certain and least certain lines not expressed in the time for the whole line. The average rate, however, is included in the table.

TABLE VI
Subject R.

II	Lgth.	M.V.	Straightness	Time	M.V.	Rate	M.V.
Most	25.4	3.1	(.9) 1.	1.07	.22	24.2	4.5
Least	24.6	2.8	(.94) 1.1	1.10	.22	23.0	3.2
IIa							
Most	31.9	2.2	(1.8) 1.3	1.46	.21	22.2	2.2
Least	32.6	1.8	(1.8) 1.	1.57	.24	21.7	3.

In accuracy the most and least certain lines are just about the same. In the time values, however, there is a difference, the most certain lines being drawn at a slightly faster rate than the least certain whether the lines are made from top to bottom or from bottom to top.

As has been said, the subject gave the order of certainty of the lines in every case. This order of certainty was, therefore, compared in every case with the characteristics of the pressure curves. It soon appeared that the line which came first in the order of certainty always had a definite form of pressure curve, and that the other lines differed from this type in a greater or less degree according to their degree of certainty. So marked was this form of curve and so universally did it hold, that it was possible to tell solely from an examination of the pressure curves

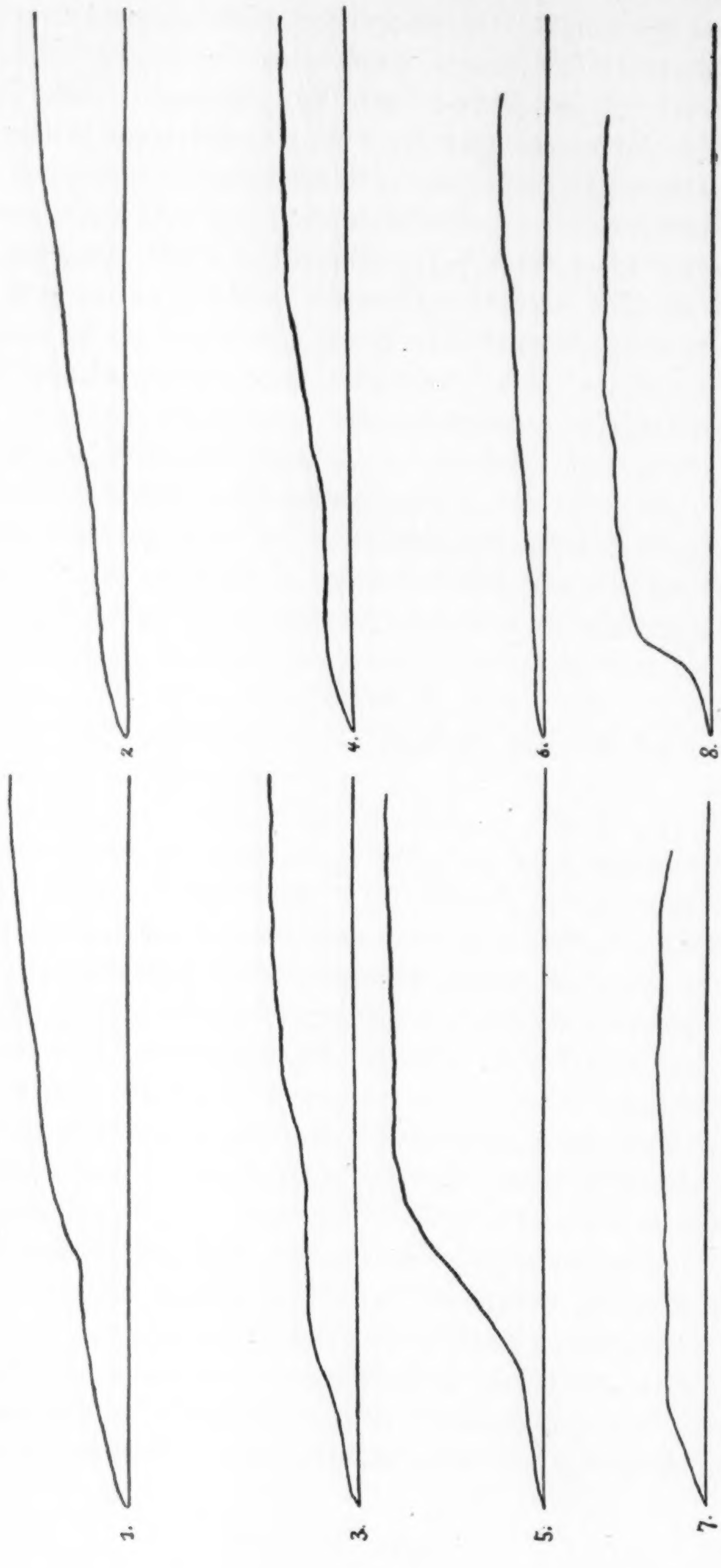


FIG. 8.

which line had been called most certain, and in nearly every case the order in which the other two followed it. This was true both of Series II and Series IIa. The "certainty" form of curve is the same for the drawings of each series. Fig. 8 shows some examples of curves taken from both series. Nos. 1 and 2 are certainty curves from Series II, Nos. 3 and 4 certainty curves from Series IIa. It will be observed that the curves follow the same form whether the lines are drawn from top to bottom or from bottom to top, reversing the mechanical process of drawing. The remaining curves in Fig. 8 are tracings of uncertainty curves from both series. They vary from the certainty type in two ways. Either the increase at the start is too rapid, as in No. 5, or the increase is more gradual as in No. 6. No. 7 is a curve from a line which the subject called "uncertain at the end." This curve shows a decrease of pressure at the end.

Not only does the curve for certainty follow a definite form, but it shows a regularity in its height as well. In the great majority (80%) of the cases the pressure curve for the most certain line is between the curves for the other two lines in height. So there is a general tendency for the certain line to be that one which is drawn with a medium pressure.

This experiment, therefore, has shown certainty in a certain part of the drawing process going with a fast rate of drawing in that part and with a definite form of reaction as shown by the pressure curve. The accuracy results which show no difference in accuracy between the certain and uncertain drawings are interesting as showing that an accurate drawing does not necessarily represent the kind of reaction characterized by certainty. The accurate drawings vary as to certainty or uncertainty with the character of their pressure curves. The same is true of the inaccurate ones.

Series III

In this series no model was used and the subjects were all given the same task. They were instructed to make a dot, raise the pencil and move it to a point perpendicularly above the dot, and draw a straight line down to, and ending in, the dot. The distance above the dot to which the pencil should be moved was

not designated. The records of the process included everything from the making of the dot to the end of the downward stroke. After a series of ten experiments had been made in this way, the subject was given special instructions each time as to the rate at which he should draw the downward line. Sometimes he was told to draw it slowly, at other times rapidly, and at other times at his natural speed. The instruction changed from experiment to experiment. This enabled the subject to get an introspective comparison between the experiences of drawing at different rates. About ten experiments were made with each of these special instructions, so that in this series there were in all about forty experiments with each subject.

The measurements for accuracy included the length of the line in millimeters, its straightness, and the amount by which it varied from the vertical where there was such variation. Where the line failed to strike the dot the horizontal and vertical distances from the end of the line to the dot were recorded in millimeters. The time measurements included the time consumed in making the dot, the time between the making of the dot and the beginning of the downward line, and the time for the downward line with the usual minor determinations.

The purpose of this arrangement is to provide a drawing process which shall be as simple as possible. The downward line is now drawn with but one determining purpose—to reach the dot. The experiments with the different subjects will be considered separately.

Subject A.—A. reports a good deal of visual imagery. Attitudes of certainty and clear visual imagery go together. This fact is observed and commented upon by the subject. He said once when he gave his introspections for an uncertain drawing, "I always feel when a line is uncertain that the visual scheme is weak."

The tables in this series give the number of attitudes of certainty and uncertainty reported by the subject in each one of the four parts of the series. They also give the average length, time, and rate of the lines for the cases of certainty and uncertainty respectively.

TABLE VII
Subject A
No special instruction

Attitude	No.	Length	Time	Rate
Certainty	4.	21.1	3.33	6.47
Uncertainty	6.	23.	3.19	7.35

Special instruction:—Natural speed

Attitude	No.	Length	Time	Rate
Certainty	3.	18.5	2.49	7.37
Uncertainty	6.	20.7	2.60	8.71

Special instruction:—Slow

Attitude	No.	Length	Time	Rate
Certainty	4.	18.9	4.20	4.46
Uncertainty	5.	23.4	5.13	4.70

Special instruction:—Fast

Attitude	No.	Length	Time	Rate
Certainty	2.	16.5	1.21	13.6
Uncertainty	1.	17.	1.30	13.
No attitude	3.	16.6	.99	18.4

This table shows no marked correspondence between attitude and length, or between attitude and time. If one rate—either fast or slow—were especially favorable for the appearance of certainty we should expect a larger percentage of attitudes of certainty in the experiments in which the instruction to draw at that rate was given. In general the certain drawings are drawn at a somewhat slower rate than the uncertain ones. The special instructions do not greatly affect the relative number of attitudes of certainty and uncertainty which appear. In the fast series when the rate becomes very fast no attitude appears.

As for the accuracy with which the subject carried out his task, the measure for this is given in the average horizontal and vertical errors. The horizontal error is the distance from the dot to the downward line, and the vertical error the vertical distance between the end of the line and the level of the dot. The average errors for all cases of certainty and all cases of uncertainty are as follows:

	Horizontal	Vertical
Certainty	.8	1.9
Uncertainty	.5	3.3

This shows that in cases of certainty, on the average, the end of the line comes nearer to the level of the dot. There is only

a slight difference in the horizontal error, it being slightly greater for the certain lines.

The pressure records in this series for this subject are very unsatisfactory, because he drew with such very light pressure that in many cases the rise in the curve was barely perceptible. No correlation is possible, therefore, between certainty and a definite type or amount of pressure. One experiment in this series, however, is especially interesting. In one drawing the subject was instructed to draw at the rate which would give him most certainty and "exert a little more pressure." The result was that the subject, following these instructions, drew with great certainty. He pronounced it "as good certainty as I've had."

In general, however, we cannot draw any conclusions from this series with this subject except the one derived from the introspections, that an attitude of certainty is always accompanied by a clear visual image.

Subject C.—With C. the introspections are quite different in character. He relies mainly upon kinaesthetic factors to guide him in the drawing process. Table VIII follows the plan of the preceding table.

TABLE VIII

Subject C

	No special instructions			
Attitude	No.	Length	Time	Rate
Certainty	10	18.9	2.60	7.0
Uncertainty	0	—	—	—
	Special instruction:—Natural speed			
Attitude	No.	Length	Time	Rate
Certainty	6	16.8	2.03	8.3
Uncertainty	0	—	—	—
No attitude	1	18.	1.52	11.8
	Special instruction:—Slow			
Attitude	No.	Length	Time	Rate
Certainty	2	13.5	4.04	3.33
Uncertainty	8	15.8	6.46	2.52
	Special instruction:—Fast			
Attitude	No.	Length	Time	Rate
Certainty	9	19.	1.13	18.6
Uncertainty	1	17.	.65	26.1

It is apparent at once from these tables that with this subject the rate of drawing has a decided influence upon the attitudes of certainty. His normal rate, as shown by the drawings made with no special instructions, is accompanied by certainty in every case. In the experiments with special instructions the ones in which he is instructed to draw at natural rate are faster than those in which no special instructions are given. In the experiments with the instruction to draw slowly the drawing is made very slowly, except in two cases in which the subject reported that he had forgotten the instruction. Great uncertainty was reported throughout these drawings, except in the two cases in which the instructions had been forgotten. The instruction to draw fast increases certainty. The fast drawings are all called particularly certain by the subject—more so even than those made with no special instructions. Only one drawing in this series shows a trace of uncertainty. This is the fastest of all the fast drawings, and we shall have occasion to refer to it again when we consider the pressure records.

The horizontal and vertical errors for the different series are as follows:

	Horizontal	Vertical
No special instruction	1.35	1.3
Instruction—Natural Speed	.60	.8
Instruction—Slow	1.20	3.5
Instruction—Fast	1.25	.85

The smaller error in the Natural speed series may be attributed to practice, since these were made after the drawings with no special instructions. The slow series in which all but one of the cases of uncertainty occur, shows a large vertical error, and so a correlation between uncertainty and inaccuracy. The inaccuracy is due to the fact that the subject stops drawing before he has come down to the level of the dot. In his introspections he says in one place that "in the slow drawings the length of the line seems greater." Evidently, then, when he draws slowly he overestimates the length of the line he is drawing.

The lines drawn with no special instructions were all certain, and their pressure curves all conform to a fixed type. This curve rises slowly and then shoots up to form a plateau at the end.

This type of curve was found to go with an attitude of certainty when the triangle was used as a model and the last stroke was a downward one. A typical example is given in Fig. 9, No. 1.

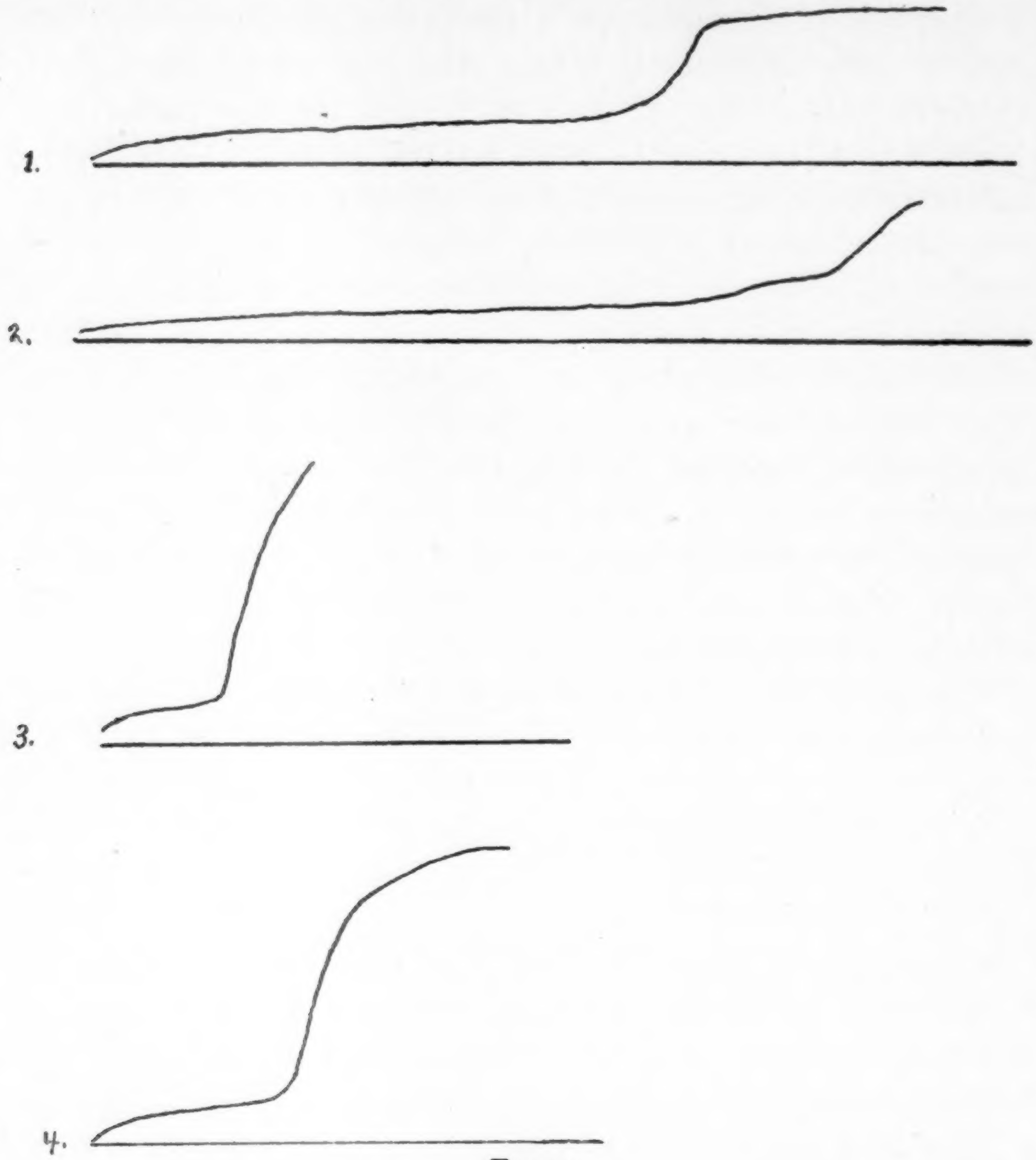


FIG. 9.

In the series with the special instructions to draw at natural speed, the curve continues to show the certainty type in three of the seven cases, but in four cases it is different. The curves of these four cases are like each other, however, and one of them is illustrated in Fig. 9, No. 2. The introspections do not show that the drawings for which these are the records are markedly different from the others except that they are somewhat less

certain. In one case certainty was reported. In another there was no attitude. In a third, certainty was reported, but it was called less in degree than that of the previous experiment, the curve of which had a plateau. In the fourth case the subject said that the line had run out of true about half-way down, but had come back, negative certainty giving way to positive.

The curves for the slow drawings may be briefly dealt with. The pressure is very slight in every case, and the plateau at the end is present in only one case. Even here it is so slight as to be scarcely noticeable. So we find that the following out of the special instruction to draw slowly has affected not only the attitude of certainty with which the drawing is made, but also the amount of pressure exerted and the form of the curve.

In the fast drawings the typical certainty curve is present in all but two cases. The curve in these cases is more like the varying form that was observed in the series with the special instruction to draw at natural speed. One of these is the drawing referred to above as the fastest of all the fast drawings—the only case of uncertainty outside the slow series. This pressure curve is shown in Fig. 9, No. 3. No. 4 shows a typical curve from the fast series.

So we find with this subject that the attitude he reports varies with the rate of drawing, and the type of pressure curve varies with the attitude.

Subject F.—In this series F. reports both types of imagery, visual-motor imagery being most prominent. With him the experiment is the same as with the other subjects and the table follows the same plan.

TABLE IX

Subject F.

No special instructions

Attitude	No.	Length	Time	Rate
Certainty	6	15.4	3.31	4.98
Uncertainty	4	14.5	3.14	4.80

Special instruction:—Natural speed

Attitude	No.	Length	Time	Rate
Certainty	4	20.2	2.83	7.26
Uncertainty	2	18.7	3.66	5.11

Special instruction:—Slow

Attitude	No.	Length	Time	Rate
Certainty	5	20	5.51	3.75
Uncertainty	3	21	5.31	4.04
No attitude	2	20	5.25	3.85

Special instruction:—Fast

Attitude	No.	Length	Time	Rate
Certainty	8	20	1.29	16.3
Uncertainty	2	19	1.64	14.5

These tables show that the subject was not as much affected by the special instructions as was C. The instruction to draw slowly does not result in any marked change in the degree of certainty or in the number of times it is reported. The instruction to draw fast, however, has such an effect, which is to make the series in general more certain. The two uncertain drawings were the first of the series. The subject had a little trouble in getting accustomed to drawing the line fast, and this is reflected in the uncertainty of the first two drawings. After these, however, the series is composed entirely of certain drawings, and the degree of certainty is great.

With this subject the greater average errors are in the certain drawings, so certainty and accuracy in this case do not go together. The average errors are as follows:

	Horizontal	Vertical
Certainty	.8	2.9
Uncertainty	.65	2.3

The pressure records with this subject show little difference between the certain and uncertain drawings when there are no special instructions, or when the instruction is to draw at natural speed. On the whole the curves of the certain drawings are more regular than those of the uncertain ones, but the difference is not great enough to show a definite type of curve for certainty, from which the uncertain curves vary. Six of the ten certain drawings show curves with characteristics similar enough to warrant our calling them all of the same form, but three of the six curves from uncertain drawings follow this form as well. Fig. 10, No. 1, illustrates a curve of this type from a certain drawing. When we come to the special instructions "slow" and "fast," however, we find that the certain and uncertain drawings have

different pressure curves. The curves for the certain drawings conform to the type found in the previous drawings, while the uncertain ones vary from it in some way. In the slow series the curves for the two drawings in which definite uncertainty was reported are very flat, showing very light pressure and very little difference in pressure between the beginning and the end of the line. They are less in amount than any of the certain drawings except one in which "only fair certainty" is reported. Fig. 10

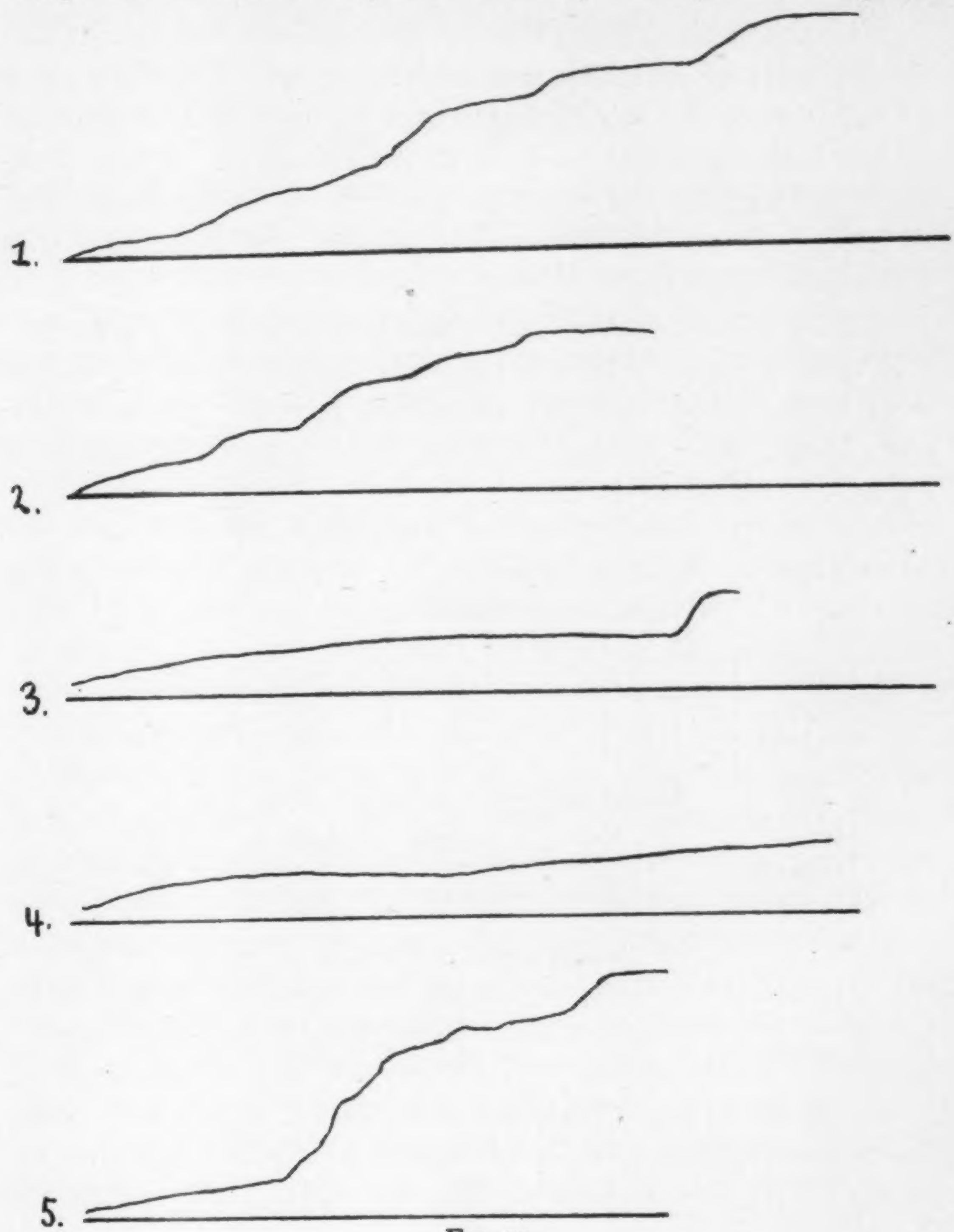


FIG. 10.

gives in Nos. 2, 3, and 4 respectively, tracings from a certain, an only moderately certain, and an uncertain drawing.

In the drawings with the instruction "fast," certainty was reported in all but the first two cases, in which the subject was becoming accustomed to the process. All the curves of this series except the first two conform to the type already found to accompany certainty. One of them is illustrated in Fig. 10, No. 5.

With this subject, therefore, we have not been able to correlate the attitudes of certainty and uncertainty with a definite form of curve when the subject has chosen his own rate of drawing, or has been instructed to draw at natural speed. When, however, he has been instructed to draw slowly or at a fast rate, differences in the objective records appear, and these vary with differences in attitude.

Subject R.—R. differs from the other subjects in the amount and kind of imagery he reports. His imagery is chiefly visual, though kinaesthetic imagery sometimes appears. Often incomplete images are reported, and sometimes part of an image is vague while the rest is clear.

TABLE X

Subject R.

No special instructions

Attitude	No.	Length	Time	Rate
Certainty	7	16.4	1.98	8.9
Uncertainty	3	18.8	2.55	7.9

Special instruction:—Natural speed

Attitude	No.	Length	Time	Rate
Certainty	4	17.6	2.20	8.5
Uncertainty	6	15.8	2.39	6.8

Special instruction:—Slow

Attitude	No.	Length	Time	Rate
Certainty	3	15.6	2.72	5.86
Uncertainty	6	15.3	3.97	4.15

Special instruction:—Fast

Attitude	No.	Length	Time	Rate
Certainty	7	16.	1.00	15.5
Uncertainty	3	13.3	1.20	11.9

These tables show a correlation between the rate of drawing and the character of the attitudes reported. The averages in all four parts of the table show that the certain lines were drawn at a faster rate, and (except with "no special instructions") they are made longer than the uncertain.

The accuracy with which the subject carries out his task seems not to have any effect upon his certainty. A comparison between the average horizontal and vertical errors of the certain and uncertain cases is given in the following table.

	Horizontal	Vertical
Certainty	1.1	2.3
Uncertainty	1.8	1.5

Turning now to the pressure curves of this series, we find that in the experiments with no special instruction, and in the ones with the instruction to draw at natural speed, the certain drawings follow a form which is rather like the form of the curve for the certain lines in the experiment with this subject in Series II and IIa. The curves for the uncertain drawings show a smaller amount of pressure, and they vary from the certainty form in other ways. They are little higher at the end than at the beginning, and sometimes show a decrease of pressure within the drawing of the line. Of the eleven cases of certainty all but four have curves of the certainty form. Among the nine cases of uncertainty only one shows a curve of the certainty form. Fig. 11 shows in No. 1 a curve from a certain drawing and in No. 2 one from an uncertain drawing.

In the slow drawings there are three cases of certainty and six of uncertainty. Two of the cases of certainty have curves of the certainty form, the curve for the third is flat. The cases of uncertainty all have flat curves that show no trace of the certainty form. One of these drawings is peculiar, however, in that it is of the usual flat uncertainty type until the very end. Then there is a little sudden increase in pressure. The curve is illustrated in Fig. 11, No. 3. The introspections on this line show that during the drawing it was attended by an attitude of uncertainty, but that at the very end there appeared an attitude of certainty.

Fig. 11.

The curves for the fast series are all of the certainty type except four. Two of these are curves for drawings which were called certain in spite of this variation. An example of a certainty curve from a fast drawing is shown in Fig. 11, No. 4.

With this subject, therefore, certainty tends again to go with a long line drawn at a fast rate, and a definite type of pressure curve. Uncertainty is correlated, though not perfectly, with a shorter line drawn at a slower rate, and a variation from the type of pressure curve found in the certain drawings. The accuracy with which the subject carries out his task, as measured by the horizontal and vertical errors, seems to have no effect upon the attitude of certainty.

Summarizing the results for Series III for all subjects, we find that there are large individual differences. These appear both in the introspective reports and in the objective records. With A. clear visual imagery and certainty go together. He is much less influenced as to his attitude by varying rates of drawing than any of the other subjects. Since his pressure records were unsatisfactory it is impossible to compare them with those of the other subjects, but it may be remarked that here as elsewhere he draws with lighter pressure than any of them. C. relies almost entirely upon kinaesthetic factors, and with him rate of drawing has a great influence upon attitude, a slow rate going with uncertainty and a fast rate with certainty. Moreover, with this subject certainty goes with a definite type of pressure curve, and when the attitude is modified with change of rate, this form of curve is modified as well. F.'s imagery is more visual than that of any of the other subjects except A. The correlation between attitude and rate is slightly better with him than with A., but not as good as with the other two subjects. With F. it is not possible to correlate the attitude of certainty with a definite form of curve when he has no special instructions or is instructed to draw at natural speed. When, however, he is drawing at a rate faster or slower than the normal, the attitude of certainty is found to be correlated with a definite type of curve. R. reports less imagery than any of the other subjects. He relies more upon kinaesthetic sensations in drawing than any of the others

except C. With him there is found a good correlation between length, time, rate, and attitude. The special instructions have more effect upon the relative number of attitudes of certainty and uncertainty reported than in the cases of A. and F., but less effect than in the case of C. With this subject (R.) there is also a fairly good correlation between certainty and a definite type of pressure curve and between uncertainty and some variation from this type.

It is worthy of special comment that the subjects form a series with regard to the completeness of the correlation between attitude and objective records. They also form a series in the imagery they report, and they are ranked in the same order in each series. With the most visual subject the correlation is least complete, and with the least visual and most kinaesthetic subject the correlation is most complete. It seems, then, that with a visualist the attitude of certainty appearing in the course of a drawing is less influenced by the rate of drawing and the pressure exerted than is the attitude of a subject who relies chiefly upon kinaesthetic factors. With the visualist the important thing for an attitude of certainty seems to be a clear visual image, with little or no relevant change in rate and pressure appearing. With the kinaesthetic subject visual imagery has little to do with the attitude which, however, does vary with the rate and pressure characteristics.

Series IV and IVa

This series, in which all the subjects took part, had for its task the drawing of a simple figure with the left hand. First the drawing was made by the left hand alone (Series IV) and then by the left hand with the right hand drawing symmetrically with it (Series IVa). In this second series the subject took two pencils and made two symmetrical drawings, one with each hand. The figures used are illustrated in Fig. 4, Nos. 6 and 7. The dotted lines in these figures indicate the path followed by the right hand when it drew with the left, though these lines did not appear in the model. The same model, illustrating the drawing to be made by the left hand, was used both when the left hand drew alone and when the right hand drew with it. It was thought

that these conditions would furnish a good contrast between the attitudes which appeared when the left hand drew alone and when the right hand drew with it. As all the subjects were right-handed, drawing even of the simplest figures with the left hand would be a very unaccustomed activity. On the basis of previous experiments it was thought that the process of carrying out this activity, with left hand alone, would be attended by attitudes of uncertainty. It was thought too that when the right hand drew a symmetrical figure at the same time, the better motor control thus gained for the left would result in greater certainty. The good motor control over symmetrical movements is well known.

Accordingly, a series of the drawings from each of two models was first made with the left hand alone. This series was completed before the series of symmetrical drawings was begun to avoid the practice effect which the symmetrical drawings would have had upon the others if they had been intermingled with them. Then the symmetrical drawings from each of the two models were made. The figures were always made continuously, that is without raising the pencil from the paper. They were begun at the top, and the left hand went first to the left and then downward, or, in the case of the second figure, obliquely to the right. In the symmetrically drawn figures the right hand followed a corresponding inverse course.

In this series the usual accuracy, time, and pressure records were taken. In the symmetrical drawings the time and pressure records were taken of the left-hand drawing only, but the right-hand drawing was measured for its accuracy. The symmetrical drawings necessitated a special arrangement of the apparatus. The right-hand drawing had to be made upon a smooth surface exactly beside the left-hand one which was made over the pressure plate. To provide an arrangement which would satisfy these conditions half the opening in the plate, H, Fig. 1, was filled up. A piece of zinc the exact size and shape of the right-hand half of the opening was cut out and soldered in place, so that the zinc simply formed a continuation of the original plate. For the right-hand drawings rectangular pieces of paper were cut out a convenient size and fixed upon this new portion of the plate.

In reporting the results of these experiments the model consisting of a horizontal and a vertical line, Fig. 4, No. 6, will be spoken of as the first model, and the one composed of the two slant lines, No. 7, will be called the second model. The lines of the first model are shorter than those of the second. In the first they are 15 mm. long, and in the second 20 mm. The angle is a right angle in each case.

The measurements of accuracy with the first figure included the lengths of the two lines in millimeters, the usual two determinations of their straightness, and the size of the angle in degrees. In the time records the time for each line was measured and the time for the drawing of the whole figure determined. In the second figure the method of measurement was a little different. The length of the two lines was measured in millimeters. There was only one determination of straightness, however. This was the number of slight fluctuations—the general deviation was not measured. The amount by which the two lines vary in direction with regard to each other is contained, however, in the measurement of the angle. The time measurements include the time for each line and the time the pencil is at rest at the apex of the angle between the two lines.

Table XI compares the accuracy records of the two series with the first model. Opposite "IV" are given the averages for the left-hand drawings when they were made with the left hand alone. Opposite "IVa" are given the averages for the left-hand drawings, and opposite "IVa R. H." the averages for the right-hand drawings, in the symmetrical series. The lengths of the horizontal and vertical lines are given under "L'gth H" and "L'gth V." Their straightness error in terms of the number of little deviations under "Str. H" and "Str. V," and their direction or amount of total deviation under "D H" and "D V." Under "angle" is given the average size of the angle in degrees. The figures in parentheses are mean variations.

TABLE XI
Accuracy (First model)
Subject A

	L'gth.H.	L'gth.V.	Str.H.	Str.V.	D.H.	D.V.	Angle
IV	12.2 (2.)	11. (1.5)	2.5	2.7	1.	2.2	105 (3.)
IVa	11.4 (1.)	11.2 (.5)	2.3	3.	1.8	3.	112 (6.)
IVaRH	10. (1.)	12. (1.)	1.3	1.4	.8	1.4	102 (3.4)

Subject C.

	L'gth.H.	L'gth.V.	Str.H.	Str.V.	D.H.	D.V.	Angle
IV	18.9 (2.3)	17.4 (2.6)	1.4	3.2	2.	2.5	90 (8.)
IVa	16.5 (2.7)	22. (3.)	2.4	2.9	1.8	3.9	101 (9.)
IVaRH	18.5 (2.2)	18.3 (1.4)	1.3	2.	2.4	2.4	90 (1.)

Subject F.

	L'gth.H.	L'gth.V.	Str.H.	Str.V.	D.H.	D.V.	Angle
IV	20.8 (1.6)	18.6 (2.1)	3.4	2.5	2.6	2.3	94 (6.)
IVa	15.8 (2.7)	15.3 (2.9)	3.	2.4	2.	3.3	107 (6.6)
IVaRH	14.1 (1.9)	15.5 (1.8)	1.	2.	1.	1.	90 (3.7)

Subject R.

	L'gth.H.	L'gth.V.	Str.H.2	Str.V.	D.H.	D.V.	Angle
IV	16.3 (2.5)	15.2 (1.6)	2.	2.7	1.7	2.	91 (4.5)
IVa	17.5 (2.9)	17.5 (3.6)	1.9	3.1	4.6	2.9	85 (7.5)
IVaRH	18. (2.)	20.8 (2.9)	1.9	2.2	2.8	4.	90 (3.)

This table shows that the addition of the right hand in the process improves slightly the accuracy with which the subject makes the drawing with his left hand as far as the equality of the lines is concerned, except in the case of C. With all the subjects, however, the errors in straightness, direction, and angle are greater when the right hand draws with the left than when the left hand draws alone. The drawing made with the right hand is in general more accurate than either of the drawings made with the left.

Table XII gives the accuracy records for the second model. Under "L'gth. 1" and "L'gth. 2" are given the average lengths of the first and second lines. The straightness values for the two lines and the average measurement of the angle follow in the other three columns. Here it will be observed that the addition of the right hand does not have as much effect upon the accuracy of the left-hand drawing as far as the equality in length of the lines is concerned. The straightness of the lines, however, is less in every case when the right hand is drawing with the left. The exactness with which the angle is approximated is not much affected.

TABLE XII

Accuracy (Second model)

Subject A.

	L'gth.1.	L'gth.2.	Str.1.	Str.2.	Angle
IV	19. (1.8)	15. (1.4)	2.8	2.6	94.6(4.8)
IVa	17.3 (1.8)	13.4 (1.2)	3.5	2.2	94. (7.)
IVaRH	14.5 (1.)	14.7 (2.2)	2.	1.	101. (6.4)

Subject C.

	L'gth.1.	L'gth.2.	Str.1.	Str.2.	Angle
IV	19.3 (3.9)	23. (3.1)	1.9	1.6	88. (6.9)
Va	18.3 (1.9)	20.9 (2.7)	2.7	1.2	90. (5.)
IVaRH	14.9 (1.1)	16.1 (1.8)	2.3	1.3	95. (4.)

Subject F.

	L'gth.1.	L'gth.2.	Str.1.	Str.2.	Angle
IV	27.6 (3.)	23.6 (2.8)	2.5	1.3	94. (6.8)
IVa	24.4 (2.2)	22.4 (2.4)	5.1	4.4	84. (6.)
IVaRH	19.7 (3.4)	15. (2.5)	1.7	1.7	103. (6.)

Subject R.

	L'gth.1.	L'gth.2.	Str.1.	Str.2.	Angle
IV	21. (1.8)	20.6 (1.9)	2.6	3.3	100. (10.)
Va	24.4 (2.8)	22.6 (3.5)	3.9	3.5	82. (9.6)
IVaRH	22. (1.2)	21.9 (2.3)	2.8	1.9	93. (6.6)

The averages for the time records of the drawings made from the first model are given in Table XIII. This table gives under "Horiz." the time for the horizontal line, under "Vert." the time for the vertical line, and under "Total" the time for the whole drawing. The figures in parentheses are mean variations.

TABLE XIII

Time (First model)

Subject A.

	Horiz.	Vert.	Total
IV	3.46 (.33)	3.02 (.52)	6.48 (.72)
IVa	3.60 (.25)	3.26 (.43)	6.86 (.49)

Subject C.

	Horiz.	Vert.	Total
IV	3.99 (.74)	3.46 (.66)	7.37 (1.35)
IVa	3.92 (.49)	2.60 (.48)	6.52 (1.08)

Subject F.

	Horiz.	Vert.	Total
IV	4.02 (.65)	3.52 (.43)	7.54 (1.07)
IVa	4.44 (.68)	3.81 (.56)	8.25 (1.13)

Subject R.

	Horiz.	Vert.	Total
IV	2.42(.30)	2.03(.27)	4.45(.52)
IVa	3.14(.28)	2.79(.37)	5.93(.59)

This table shows that with all the subjects except C. the addition of the right hand results in slower time. With C. it results in a faster time. The time records for the second model are given in Table XIV.

TABLE XIV

Time (Second model)

Subject A.

	1.	Point	2.	Total
IV	3.26	.50	2.61	6.37
IVa	3.55	.49	2.77	6.81

Subject C.

	1.	Point	2.	Total
IV	3.67	1.47	3.34	8.48
IVa	4.00	1.12	3.25	8.37

Subject F.

	1.	Point	2.	Total
IV	3.81	.95	3.64	8.40
IVa	4.82	.69	4.54	10.05

Subject R.

	1.	Point	2.	Total
IV	2.22	.59	2.29	5.10
IVa	2.78	.49	2.42	5.69

This table shows that the addition of the right hand gives a slower rate of drawing for all subjects except C. With him the rate is slightly faster again.

The introspections, in so far as they have to do with the relative certainty with which the figures are drawn under the two different conditions, give a wholly unexpected result. It appears from them that the addition of the right hand does not increase the subject's certainty with regard to the left-hand drawing, but decreases it instead. The introspections, however, furnish the explanation for this result. All the subjects reported that their attention was for the most part upon the left-hand drawing, but that it would shift over at times to the right-hand one. This

would occur several times in the course of the drawing of a given figure. It occurred most often in the case of F., who reported that attention oscillated between the two drawings as many as seven or eight times in the course of the process. This shifting of the attention occurred least often in the case of C. He was the only subject who seemed able to keep his attention upon both drawings at once. The time results show that C. was the only subject for whom the addition of the right hand did not result in longer drawing times.

The pressure records may be briefly dealt with. They do not show a different form of curve for each series. The typical form of the record of pressure changes is the same for the subject's left hand whether it is drawing alone or with the right hand drawing at the same time. Thus we have two series, one more certain than the other, yielding pressure curves which do not reflect this difference in attitude. The accuracy records of the two series are little different. The time records do show a difference between the series, for in the case of all the subjects except C. the time is somewhat longer for the less certain series. This, however, by itself is not very significant, and for the explanation of these results we must turn to the introspections already mentioned. The addition of the right hand in the drawing process, changing as it does the subject's total reaction, brings about a change in attitude too, and this change is experienced introspectively as a dividing of the attention, or a shift of the attention from the left hand. Thus, although the objective form of the left hand's reaction remains the same (except in its time characteristics), the change in the subject's total reaction has brought about a change in attitude. Introspectively this is designated as distraction of the attention, and it is natural that a slower rate of drawing should be found to accompany it. The case of C. is worthy of special comment. Of the four subjects he was least affected with regard to his attitude of certainty by the addition of the right hand. He is also the subject who has shown himself throughout to depend most upon kinaesthetic sensations and images. He seems to have had less difficulty than any of the others in adopting the new form of symmetrical draw-

ing. His time records show that instead of lengthening the time of the drawing, as is the case with the other subjects, the addition of the right hand actually shortened it a little. It appears, then, that the subject who makes greatest use of kinaesthetic factors is least affected by the change in the form of the total reaction made by the addition of the right hand in the drawing process.

Summary and Conclusion

The purpose of our investigation was to see whether there was a correlation between the conscious attitudes experienced by the subject in connection with his reaction to certain instructions, and the objective form of the reaction as measured by its accuracy, rate, and pressure. We now summarize briefly the results of the experiments.

In the first place, the practice series yields nothing of final value except the indication that the attitude of certainty in some given part of the process may be correlated with a slightly faster rate of drawing.

Series II, IIa and IIb, in which each subject was given a different task, yield results which differ in their definiteness, some of the figures being better suited to the purposes of the experiment than others. With A., who drew the two series of circles, the first anti-clockwise and the second clockwise, the introspections showed that the second halves of the circles were always less certain than the first halves. The time records show that the rate of drawing increases during the first half and decreases during the second half. The pressure records show that in both series the pressure of the first half rises gradually and regularly with never a decrease, while in the second halves this regular increase is not continued, irregularities occur, and sometimes a decrease in pressure appears. In the anti-clockwise circles a point of maximum uncertainty was located in six of the experiments. This point always came in the third, or between the third and fourth quarters of the circle. The time records show that when it is thus located it comes at the point at which the greatest retardation in rate is taking place, and the pressure records show that at this point too there is a decrease in the amount of pres-

sure. Thus, in this series for this subject certainty seems to be correlated with an increasing rate of drawing and steadily increasing pressure; uncertainty with a decreasing rate and irregular pressure characteristics.

The triangle figure used in Series II and IIa with C. proved to be very unsatisfactory. The results did, however, give some indication that the attitude of certainty is accompanied by a more regular pressure curve than the attitude of uncertainty. Where the figure ended in a downward stroke (Series IIa) an attitude of certainty was sometimes reported during the drawing of the last line. When so reported the pressure curve of the drawing was found to end in a "plateau."

With F., whose task in Series II and IIa was the drawing of four slant lines combined in two different ways, it is found that in general certainty goes with a longer line and a faster rate of drawing than does uncertainty, and the lines which are mechanically easy for the subject to execute are usually the lines drawn in this way. This, however, does not necessarily hold throughout, because the first line in each drawing is the most certain, although in the first drawing it is mechanically easy and in the second mechanically difficult. This certainty is correlated with a definite form of pressure curve which is followed in the drawing of the first line throughout, and is departed from only in the two cases in which this first line is called uncertain. In the other lines marked contrasts in subjective certainty are reflected in differences in the pressure curves, but small differences are not so reflected.

The most satisfactory figure in Series II and IIa proved to be the four vertical lines which formed the task for R. He was usually able in his introspective report to rank the lines in their order of certainty, and this gave a good basis of comparison with the records of accuracy, time, and pressure. The most certain and least certain lines of each experiment were compared for accuracy and time. It was found that there is practically no difference in accuracy between the most certain and the least certain lines, but the most certain lines are drawn at a somewhat faster rate than the least certain. As for pressure, it is found

that there is a very definite form of curve which always goes with certainty, and a variation from that form of curve always goes with uncertainty, this variation being greater or less according as the degree of uncertainty is greater or less. In most cases also the curve for the most certain line is between the other two in height, this holding in 80% of the cases. These results hold both in Series II, in which the lines were drawn downward, and in Series IIa, in which they were drawn upward. Thus, in this series with this subject we find that the accuracy of the drawing has no effect upon the attitude experienced in connection with it. The time, however, is less for the certain than for the uncertain lines, and a definite form of pressure curve is found to go with certainty, and some variation from this form with uncertainty.

In Series III, in which the task was drawing down to a point, the special instructions as to the rate of drawing were given. The subjects are differently affected by these instructions. A. is least affected, and as his pressure records are unsatisfactory very little can be drawn from his results, except that the introspections show that an attitude of certainty is always accompanied by a clear visual image. C. is most affected by the special instructions, the instruction to draw fast resulting in a large increase, and the instruction to draw slowly, resulting in a large decrease in the number of attitudes of certainty reported. The pressure records throughout for this subject show a correlation between certainty and a definite type of curve. With F. no noticeable change in the number of attitudes of certainty is brought about by the instruction to draw at a slow rate, but with the instruction to draw at a fast rate the number of attitudes of certainty is increased. This subject draws at a slower rate naturally than any of the others as shown by his records throughout. With this subject no correlation was found between certainty and a definite type of pressure curve in the series in which there were no special instructions and in the series in which the instruction was to draw at natural speed; but in the series in which the special instructions were to draw at a slow or at a fast rate, this correlation was found. With this subject in Series II and IIa it was found that large differences in subjective certainty were reflected

in the pressure records, but that for small differences no corresponding objective differences could be determined. So also here, it seems that the instructions "slow" and "fast," increasing as they do the subjective differences in attitude, make the objective changes in pressure great enough to be recognized. This subject drew with greater pressure than any of the others, and seemed throughout less sensitive than they to small differences in pressure. The results of this series with R. are quite analogous to those already obtained with him in the previous series. Certainty is found to go with a long line, a fast rate of drawing, and a definite type of pressure curve, and as before with him the accuracy of drawing seems to have no effect upon his certainty. The individual differences exhibited by the subjects in this series are interesting in that they seem to show that persons of different imaginal type are affected in different degrees by the same special instructions.

Series IV gave an unexpected result. It was thought that when the right hand was added in the drawing process greater certainty in the drawing made with the left hand would be the result of the better motor control afforded by the symmetrical movement. It was found that the reverse was the case, the subject reporting less certainty when the right hand drew with the left than when the left hand drew alone. The objective records show that there is little difference in accuracy, and no definite difference in the pressure characteristics between the two series of left-hand drawings. The time records, however, show that the drawings made by the left hand when the right hand is drawing symmetrically with it are made slightly more slowly than when the left hand draws alone, except in the case of C. Thus we find that the only difference in the objective records made by the change in the total form of the reaction which comes with the addition of the right hand is a slight increase in time in the case of three of the four subjects. Nevertheless, the introspective reports betray that with this change in the total form of the reaction there comes a change in attitude in the direction of less certainty. This is described subjectively as a shifting of the attention from one drawing, or one part of the reaction, to the

other. Thus, with a change in the total reaction we find a change in attitude. Subject C., who was least affected as to his attitude by the change, is also the only subject whose time is not lengthened, and he is the subject who throughout the investigation has been found to use chiefly kinaesthetic imagery. Here again, therefore, we find an instance of imaginal type characterizing the degree of change of attitude under special conditions.

The general result of our investigation is positive. In spite of numerous exceptions and some incomplete records, the results are sufficiently uniform and definite to show that under the conditions of our experiment some objective characteristics of the subject's reaction vary with his introspective attitude. The accuracy of the drawing seems less important than the other characteristics for the appearance of certainty. In some cases greater accuracy and certainty go together, but more often with the same subjects they do not. As for the time factor, certainty is usually found to go with a faster, and especially with an accelerating rate of drawing. Certainty is found also in most cases to be correlated with a definite type of pressure curve, and uncertainty with a variation from this type. In some cases, to be sure, notably with subject F., this correlation does not hold between small differences in attitude, but since it holds between large differences, this lack of complete correlation may be attributed to the crudeness of the apparatus which is not sensitive enough to show slight objective changes. In Series IV and IVa we find no appreciable change in the pressure curves of the left-hand drawings —the form of the left hand's reaction is the same in both cases. In this series the difference in subjective reaction is, however, correlated with the difference in the subject's total reaction which is brought about by the introduction of his right hand into the process.

The objective characteristics that we have measured with our apparatus, though they are directly involved in carrying out the instructions, are by no means the only ones that might vary with the changes in subjective attitude. Unconscious eye-movements, incipient movements of the limbs (especially of the arm and hand not used in the drawing), innervations of the larynx, etc.,

might all be part of the subject's reaction to the instructions and might vary with his attitude, just as we have been able to show that certain characteristics of the movements most obviously involved in his reaction vary with changes in attitude. Since it is possible that any of these other motor processes might have been as closely and perhaps more significantly correlated with the attitudes of certainty and uncertainty, the writer hesitates to claim anything final for his results. The investigation is regarded rather as a tentative, exploratory one. The results in his estimation do demonstrate that the conscious attitude is accompanied by relevant objective differences in bodily reaction, and he ventures to express the hope that other investigators will be encouraged to follow up a line of investigation which appeals to him a promising one.

REFERENCES

1. Freeman, F. N. Preliminary experiments on writing reactions. *Psychol. Rev. Monog. Suppl.*, 1907, 8, 301-309.
2. Judd, C. H. Movement and consciousness. *Psychol. Rev. Monog. Suppl.*, 1905, 7, 199-226.

COMPLEX REACTIONS OF THE DOG: A PRELIMINARY STUDY[1]

ARTHUR HOWARD SUTHERLAND, PH.D.
Instructor in Psychology
Yale University

This study, originally begun with the hope of approaching the number processes (counting, estimating, or reacting to number) began with an attempt to set up rhythms of action on the part of the dogs. Its scope as here reported covers the preliminary stages in the process of learning, and became, necessarily, a study of methods. The apparatus used can be manipulated from outside the experimental room, and is fully described. The training series is described in a way which has not heretofore been done, and is advocated as an equalizer of animals which inevitably differ in a large number of respects. Certain observations regarding the transfer of habits learned in one series, and of the retention, seem important enough to present at this time. The method of treating the data of the experiment has also some novel features and leads to the conclusion that the evidence for discrimination is to be looked for in the integration of acts, which demands a special display of results, rather than a table of summary averages of accuracy.

Two pertinent criticisms have come from the Chicago laboratory with regard to current studies of discrimination in animals. One deals with the method of treatment of data, the other with the nature of the stimuli. Hicks and Carr (3) have shown that the percentage method of tabulation of results of learning does not accurately nor adequately represent the activities of the animals under investigation. It follows that a percentage of error curve is, for psychological purposes, an uncertain datum for inferences. And Miss Weidensall (10) has shown that when a black and a white surface are presented to an animal (for discrimination), the white surface is of greater importance in modifying the behavior than is the black, and that what appears to be a discrimination may prove to be a "simple recognition." If these two criticisms are accepted, it is clear that the evidence

[1] I wish to acknowledge with pleasure my indebtedness to Dr. J. M. Flint of the Department of Surgery in the Yale School of Medicine, for the use of dogs and quarters in which to carry on this experiment.

for discrimination in animals is seriously undermined; also that the treatment of the results of behavior must be revised if discrimination, in the psychological sense, is to be demonstrated.

With a view to contributing to this question, the present preliminary study was undertaken as an approach to a fuller investigation of more complex processes of intelligence, especially the so-called "number" or "counting" processes. The experiment has failed to reach a point at which any contribution can be made to the latter problem, and this report presents only the behavior in the beginning stages of learning.

It is possible to exhibit behavior of animals in different ways. If the experimenter is interested in a statistical problem, percentages of error, averages, means, standard deviations, etc., are important, and from them certain conclusions can be drawn regarding the adaptation of animals to a given situation. But the successes and failures, the right and wrong choices, summarized in a percentage, conceal rather than exhibit the actual behavior of an animal in response to a controlled stimulus, and encourage generalized statements regarding groups of animals. In analyzing specific varieties of behavior, therefore, such as that involved in discrimination, this concealed behavior must be taken account of. And since the effort is to discover whether a certain type of internal behavior accompanies the external manifestations of choice, it would appear that a mere "Success or Failure" summary of external manifestations must inevitably fail to yield the desired data. Conclusions as to animal discrimination have therefore been mainly negative and, when positive conclusions were drawn, reviewers have frequently suggested a faulty technique.

But if an adequate description of the actual behavior were given, certain positive data would be available as to the processes of the animals. Hence, more complete descriptions rather than the experimenter's summary conclusions are needed in order that the science of behavior may progress by cumulative results. Not "do animals or these animals discriminate?" but "what processes are now going on in this animal?" is the pertinent question. And only complete descriptions, in other than percentage terms, will

yield the desired data. The present report, therefore, is concerned with the behavior, and the analysis of behavior, of dogs in learning a visual discrimination. The rate of progress of the learning suggests a slow integration of various acts of the behavior, and the presentation emphasizes this by showing the relation of the choices to an integrated rhythmic activity.

Historical

Johnson (6) has reviewed critically the experimental work of Kalischer, Munk, Rothmann, Swift, and others. In his own dogs, he was able to discover no conclusive evidence of discrimination of pitches, but succeeded in setting up an association between food and noises, in which the localization of the noises apparently controlled the reactions. E. M. Smith (7) found his dogs able to make color discriminations "weak, unstable and easily inhibited by differences of luminosity." Colvin and Burford (1) found that changes of form inhibit color discrimination in dogs. Hunter (5) succeeded in setting up a visual discrimination (?) in the case of two dogs to the extent of 72% and 60% accuracy out of 560 and 650 trials. The experiment was characterized by "helplessness on the part of the dogs" and a "lack of resourcefulness." The position of the dog's head at the moment of release seemed to determine the direction of movement. Successive choices tended to encourage the maintenance of an orientation motor attitude for periods of increasing length. Franken (2) had earlier characterized similar reactions as "sensory thought processes." The use of this rubric is justified by Franken from the fact that the reaction is the release of an expectant attitude—as contrasted with reactions which are immediate (p. 51). If the animal possesses expectant attention, it possesses the necessary rudimentary organization of intelligence for thought processes.

The Dogs

Six dogs, three male and three female, were used. The animals are referred to as BTF (Black Terrier, female); BF (Black, female); BrF (Brown, female); BM (Black, male); BBM (Brown Bull, male); WM (White, male). These dogs were

mongrels and had been confined to the kennels for varying periods. The precise ages and experience of the dogs were unknown. In the kennel the males were fighters; the females were smaller, younger and more docile.

The use of dogs picked up from the street has been criticized by many authors. The chief objection seems to be that on account of a lack of knowledge regarding the previous experience of the animals, it may be that the behavior observed in the experiment is simply a repetition of behavior already learned elsewhere, and that the experimental conditions do not control the action, and particularly the learning. But the same objection may be urged against two dogs which have been reared in the laboratory. There is no typical dog. Each one shows marked individual differences. It seems desirable, therefore, to devise a method which shall equalize these differences to some degree, and bring the animals to a common basis for comparison. Not only is this necessary in order that the grouping of results from a single experiment may be valid; but it is the only means by which various pieces of work may be adequately compared. So far as is known this equalizing has not heretofore been done systematically. Vague references to a training series leave one in the dark as to the steps employed. In the present experiment a simple alternating habit was developed as a basis of comparison, and the growth of this rhythmical habit is fully described. And while this method is believed to equalize the dogs upon a level for a psychological experiment, we have preferred to hold these results as tentative until the method can be used upon young dogs.

Notes on Behavior in Learning the Alternating Habit

In view of criticisms relative to the presence of an experimenter or master in the vicinity of the dog while choosing, and to rule out the possibility of unconscious signs from which the dogs might take the cue, it was so arranged that from the beginning of experimental work proper (after preliminary training), the experimenter was absent from the room in which the reactions and choices took place. This necessitated a training series which

was carefully watched. For this purpose Apparatus A, a modified form of the Yerkes light discrimination box, was used (Fig. 1). The apparatus was reduced to two parallel alleys open at one end. During the first month the animals were trained by regularly progressive steps to pass alternately from one alley to the other, securing in each a piece of meat.

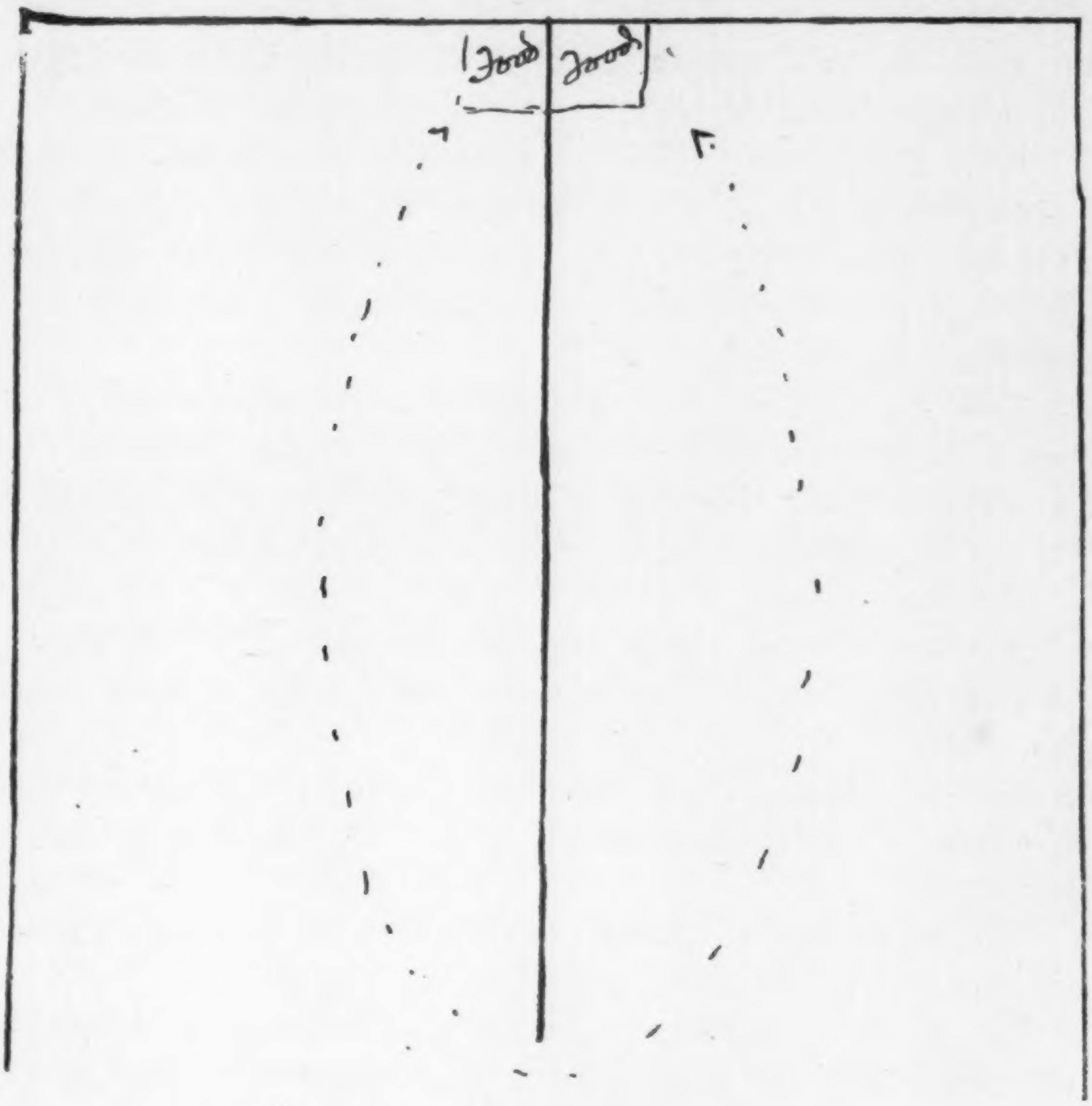


FIG. 1.—Apparatus A

Nov. 20, 1914. Each dog was taken to the apparatus room in turn, and fed at the food box in each alley of the apparatus. All the animals betrayed signs of awareness of the presence of food, three coming again and again to the vicinity of the meat, standing rigidly and with lips wrinkling. Each dog was permitted to investigate the room and apparatus so far as he would.

When the lights were extinguished, the dogs crouched close to the experimenter's feet. All tended to follow the experimenter's movments, but in different degree of proximity. BF, BM, and WM gave evidences of fright. It was found necessary to drag them into the apparatus and up to the food box, and immediately after snatching the meat, they would back away to the room outside the apparatus.

Nov. 21. Same. Less appearance of fright.

Nov. 22. WM still showed signs of fear and had to be dragged to the food box. All others stood quietly by the food box.

Nov. 23. With a piece of meat held just before the dog's nose, the dog was led to and fro about the room, and finally into the apparatus, being fed only at the food box. WM, this day, seemed less fearful, but it was still necessary to pull him to the apparatus occasionally.

Nov. 24. Same. BrF, introduced to the experiment at this point (to take the place of another dog which had died), showed no signs of fear. The experimenter took his stand in the center of the apparatus and led the dogs from alley to alley.

Nov. 25. Same.

Nov. 26. Same. Dogs now ran around behind the experimenter from one alley into the opposite alley without much coaxing.

Nov. 27. Same. Dogs would start to run to the opposite side if anything was dropped on the floor. They apparently waited for a cue.

Nov. 28 to Dec. 3. Same. If meat was not in evidence when the dog arrived, he would scratch at the trap door.

Dec. 4. Food loaded at opposite ends of alternate shelves of the chute (Fig. 2), so as to drop first in one alley, then in the opposite. The experimenter took his stand outside the apparatus without disturbing the reactions.

Dec. 5. Same. WM gave no evidence of fear.

Dec. 6-10. Same. Dogs proceeded rhythmically from one alley to the other.

Dec. 11. Experimenter took his stand at N, the doorway of the room. BrF, WM, BF, BTF each stopped several times to

look at the experimenter, but proceeded without overt encouragement.

Dec. 12-16. Same.

Dec. 17. During this day's run the experimenter backed still further out of the room without inhibiting the dogs' behavior.

Dec. 18-20. The experimenter did not advance into the room during these three days. During parts of the run, he stepped out of sight, being guided in the operation of the apparatus by the sounds of the dogs' movements.

It will appear from these notes that one month was consumed in setting up an alternating habit which would run its course during each day regardless of the presence of the experimenter. Whatever cues may have set off the adjustment, they did not come from the experimenter. In bright light, as also in a dim light which just permitted the dog to be seen, a pendular-like swing was set up, with a short stop at each end of the swing, and continued until no more food was found.

No systematic tests were made as to the length of time the rhythm persisted after the failure to secure food. Since the swings did continue, however, the cue to the continuation of the rhythm was not invariably the just prior "act of securing the food." Sight, sound and odor of food about to be secured likewise were excluded. But sights and odors, so far as they referred to the total situation, were not excluded, and it is quite possible that these, together with the kinaesthetic and organic qualities involved in approaching the position at which the food is usually obtained, are to be looked to for explanation of this behavior. To make a general test of the effect of the presence of a larger amount of odor, the front of the chute was removed so that all the meat except that on the four lower shelves was exposed. No effect could be observed in the dogs' behavior.

The experiment with controlled stimuli begins, then, at this point (with an unknown number of influential factors) and should proceed analytically in the control and variation of each. This is of course similar to the case of any human or other animal experiment. In the human being, a complex set of fairly well automatized language habits takes the place of this simple alter-

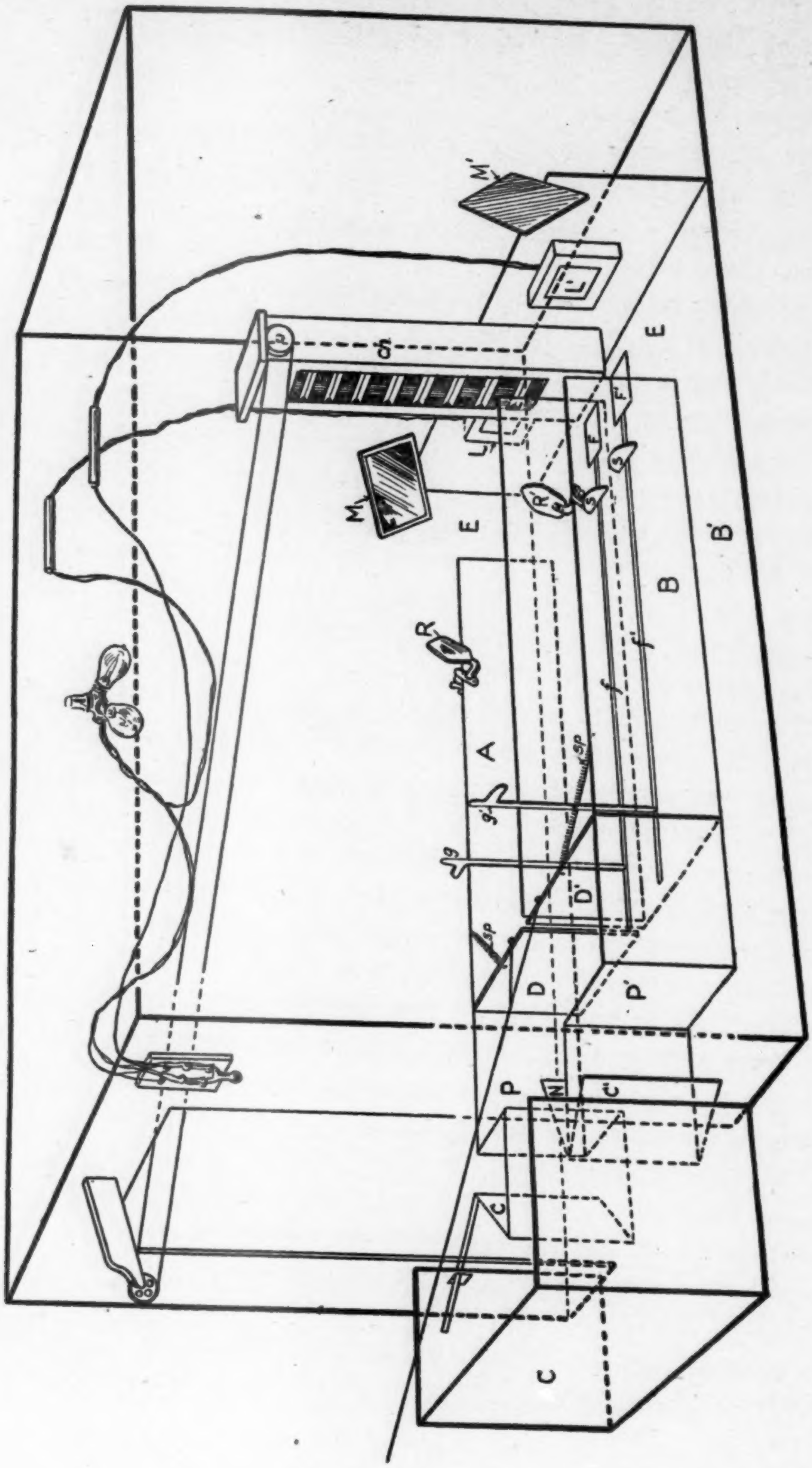


FIG. 2, Apparatus B.

nating habit, and by the variations of the verbal expressions the experimenter infers the experience of his human subject. The alternating habit of the dogs is far less complex but has the same function, so that in the present experiment we have the advantage of a single simple adjustment, the variations of which will betray the relative influence of the stimuli used. It now becomes necessary to determine whether this simple alternating habit can be broken up or complicated by means of such stimuli, without the presence of the experimenter.

Herewith (Fig. 2) is shown a perspective drawing of the experimental room and the apparatus. The walls of the room were lined with black cloth, and the starting box (C) and the doorway were also covered so as to exclude any visual stimuli from the outside. The dog was brought to the starting box, and there confined until the apparatus was adjusted. The doors, D and D′, were then pulled back, the small door, N, releasing the animal into the vestibule through a narrow passageway which necessarily gave him a direct orientation toward the two alleys. Having passed into one of the alleys, the doors D and D′ were closed behind him, the further pathway leading through the exit, E or E′, through the return alleys, A′ or B′, through the small doors, c or c′, back to the starting box, C.

After a few days' experience, it was found no longer necessary to close the doors behind the dogs, since they proceeded along the pathway back to the starting box. The reactions therefore involved a more or less continuous run (for sixteen choices), the animals stopping only to secure the piece of meat at the foot of the chute.

In greater detail the additions to the apparatus as found in Fig. 2 may be described under the following headings, *Food Chute, Stimulus Lights and Wiring, Reflectors, Screen, Dumping Apparatus, Movable Partitions, Starting Box, Operation of Doors, Curtains.*

Food Chute: In order to drop a piece of meat at the appropriate spot in the apparatus, a chute was devised, CH. This is an enclosed box 5 ft. x 6 in. x 6 in. set upright midway between the two alleys, in an opening at the end of the mid partition. Within the box are two horizontal shafts, over which runs a broad endless belt. The belt carries 16 shelves, each 1 in. deep and 5 in. long, set so that each end hangs over the corresponding alley. The shelves are 3 in. apart upon the belt. Attached to the outside end of the

upper shaft is a pulley and over this pulley runs a cord to another pulley outside the experimental room. When the cord is pulled, the belt carries the shelves downward and as each one reaches and passes around the lower shaft, it deposits its contents at the foot of the chute. Before the dog was brought to the experimental room, the chute was loaded, by placing sixteen pieces of meat (rolled in cornstarch so that they would slip) upon the shelves in such a way as to drop at F and at F′ in an order determined on for that day, or series. The experimenter may thus stand outside the experimental room and while the dog is returning to the starting-box, drop another piece of meat in the same or the opposite alley and be ready for the succeeding reaction.

Reflectors. Two mirrors, at M and M′, were set to reflect an image of F and F′ to a hole in the wall at the experimenter's station. From this station the experimenter therefore could observe any failure of the apparatus. To intensify the brightness of the image of F and F′, small mirrors were set at R and R′, at the top of the side partitions of the alleys A and B. These reflect a beam of light from the stimulus lights to the foot of the Food Chute.

The Stimulus Lights. A row of five sockets for 110 v. finger size heat lamps was placed upon a support, and this support attached to the wall at the end of the alley. The lamps were wired in parallel so that one or five lamps could be used. The tops of the lights were visible through a rectangular opening, six by four inches. The number of lights used differs for the several series and is discussed in that connection. In the later series, one or more lights were shown in both alleys, and to facilitate the manipulation of the stimulus lights, a special wire was run directly from the main current to the number of sockets necessary. A double knife switch upon the wall outside of the room at the experimenter's station, controlled the remainder of the lights, so that a single throw of the switch turned out the lights in one alley, except those on the direct wire, and turned on the corresponding lights in the other alley. It is the stimulus lights, L and L′, which reflect from the small mirrors, R and R′, to the foot of the Food Chute. This serves the double purpose of giving to the experimenter a brighter image of the food position, and also enables the dog more easily to locate the piece of meat.

Screen. A small wooden screen at S and S′ likewise serves a double purpose of shielding the food from the dog until he has entered the alley far enough that the doors may be closed behind him, and also as a scrape in connection with the dumping apparatus.

The Dumping Apparatus. If the dog chooses the wrong alley, i.e., the one from which proper stimulus and food are lacking, the piece of meat must be removed before the next reaction occurs. To accomplish this conveniently, a hole through the floor at the foot of the chute, is covered with a paddle shaped trap door, F and F′. This trap door slides under the screen, S and S′, and its contents are scraped off and fall through the hole in the floor. The mechanism for operating the trap is a long arm, f and f′, which slides along the floor between guides. At g and g′ an upright arm rests in a malleable iron socket upon the long arm. The upright arm is fixed at its center to the mid partition, its upper end being free. To operate the trap,

therefore, it is only necessary to push forward upon this upright lever. Reversing the movement closes the trap again.

Movable Parts. To give the animal the best possible orientation toward the lights, as it leaves the starting box, the right angle parts, P and P′, were devised. These are pushed back out of the way when the apparatus is not in use. The doors, N, c and c′, are attached to these movable parts.

The *Starting Box,* C, is a three sided, hinged box, the open side being directed toward the apparatus. The top is covered over with cloth so that an animal within cannot see what is going on around the box. This covering also extends up over the doorway of the room during the course of the experiment. To open and close the doors, c and c′, a slender rod[2] was fastened to the top of each, and passed through holes in the wall of the room, to the experimenter's stand. The same method is used for working the levers of the dumping apparatus. The doors, D and D′, are kept closed by the springs, Sp and Sp′, and are opened by pulling upon a cord which branches at its mid point, sending one branch to each door.

No means of punishment has been used in connection with the experiment thus far. For purposes of this preliminary series, absence of punishment was decided on in order to introduce no factors which might prove to be inhibitory of the dog's reactions.

First Series

In the first series, one light was shown, at L or L′. Meat was to be found at F or F′—in the alley in which the light was shown. The overhead light was turned off so that the room was dark except for the single stimulus light. The light was shown, for successive choices, in the following order (B = Right alley, A = Left alley): B, B, A, A, B, A, A, B, A, B, B, A, B, B, A, A—16 choices, half in alley B, and half in alley A. Will the alternating habit of the preliminary series persist, or will the dog show a preference for the light or for the dark alley? The only respect in which the conditions were changed from the preceding training series was in the location and intensity of light.

During the first ten days of this experiment, the dog was held at N by a long leash extending through and hooked to the wall (instead of in a starting box, as later). When the apparatus was ready for operation, the loop in the leash was pushed from the hook, the doors, D and D′, opened so that the light from the

[2] A part of the apparatus devised by the writer in connection with some work on Color Vision in Cats in 1907 with the Watson Spectral Light Apparatus,—unpublished.

stimulus lamp shone upon the dog, which then leaped forward into the apparatus, either alley B or alley A. By means of the long leash, the dog was then returned to N for another choice. After the tenth day, the dog followed on his own account the pathway through the return alleys to the starting box, C, from which it was released by opening the door, N, further to guard against possible influence of the dog by the experimenter.

For purposes of comparison, the percentage of error curves are given (Fig. 3) for each dog, and an average curve for the group of 6 dogs. They show that on the first day all of the dogs except one (WM) were successful in more than 50% of the choices, varying between 56.25% and 68.75%, WM being successful in 37.25% of the choices. On the second day, two of the dogs were less successful, one equally, and three more successful than on the first day. On the third day, all except one were more successful than on the second day. On the fourth day, one dog ran a perfect series, four improved, one held his record of the day before. On the fifth day, two were more successful, four were less successful, etc.

These records show that the discrimination of a light from a dark alley, widely different as these seem to be, is a difficult undertaking under the present conditions. Is this difficulty due to the previously established alternating habit? The percentages conceal the evidence on this question, and another means must be had to exhibit the actual behavior of the dogs. Behaviorism has not yet devised a terminology and the difficulties are therefore enhanced.

The day's run in the present series consisted of 16 choices; and after the first choice, the ensuing behavior may be brought under two lesser types—respectively "succession" and "alternation." Having made a choice of alley A (let us say), if the dog repeats his trip to alley A after returning to the starting box, he is credited with a "succession." If, however, the dog goes on the second choice to alley B, he is credited with an "alternation." The behavior in each series may thus be stated in terms of "successions" and "alternations."

The lights were shown in an order which, if perfectly followed, would have required 6 "successions" and 9 "alternations." In

the preliminary training series, the dog had learned to make 15 "alternations" per day. On the first day of the present series the "succession" type of behavior predominated, as follows:

Table I

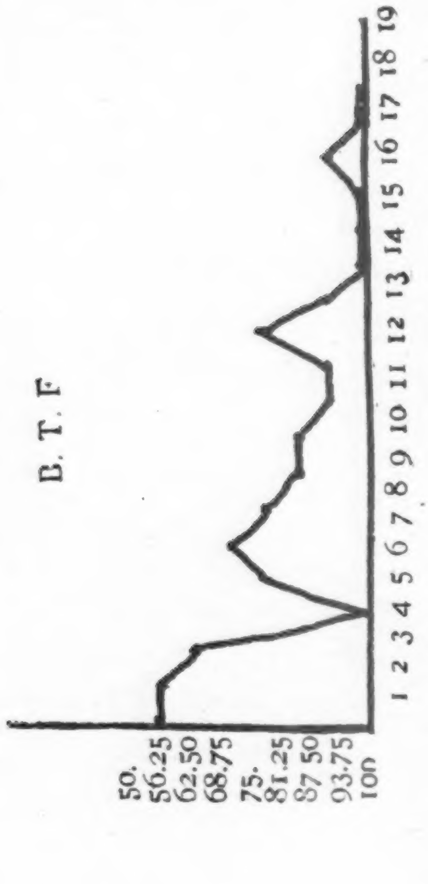
Dog	Behavior		No. Successful	% Successful	% of 15	Sum total %
BTF	Suc.	11	7	.636	.467	
	Alt.	4	3	.75	.20	.667
BF	Suc.	12	7	.58	.467	
	Alt.	3	3	1.00	.2	.667
BrF	Suc.	9	5	.55	.33	
	Alt.	6	3	.50	.2	.53
BBM	Suc.	5	2	.40	.13	
	Alt.	10	7	.70	.467	.60
BM	Suc.	9	5	.55	.33	
	Alt.	6	3	.50	.2	.53
WM	Suc.	8	3	.37	.2	
	Alt.	7	3	.43	.2	.40

It is at once clear by reference to the above table, that the difficulty does not lie in the persistence of the alternating habit, except in the case of BBM.

Transfer of Training

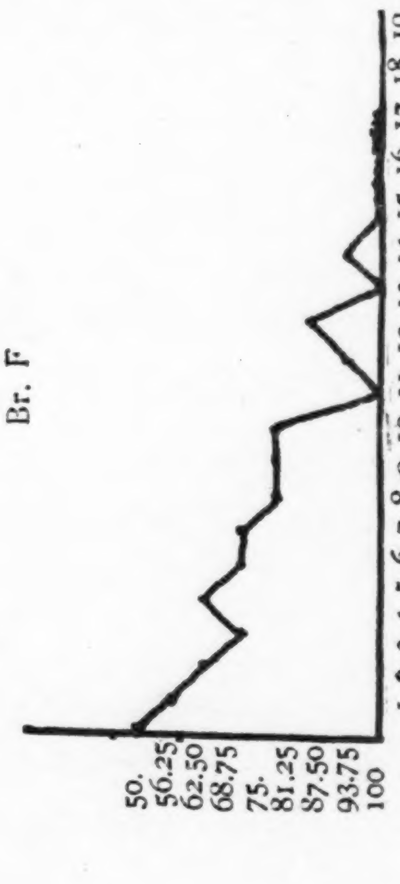
The first experimental series, from the human point of view, required merely a slight modification of the preliminary series. It was different from the preliminary training series by the number of "successions" required, in place of a similar number of "alternations." The "successions" were interpolated among the "alternations" in the following order—S, A, S, A, A, S, A, A, A, S, A, A, S, A, S. The change of location and intensity of light made the situation sufficiently different to inhibit the transfer of the alternating habit. Was there, however, a position error on the first day of the series, and if so, on which side? My records show, 1st, that any position error present the first day was eradicated after the third day. (BTF made a perfect score on the fourth day); 2nd, that BBM, whose tendency was to continue the rhythmical habit on the first day, showed more "successions" than "alternations" on the second day; 3rd, that BF and BM developed a pronounced tendency toward "successions" on the third day. A further examination of the records shows that this last apparent tendency was a sporadic affair which persisted only for the one day.

B. T. F



Curve I.

Br. F

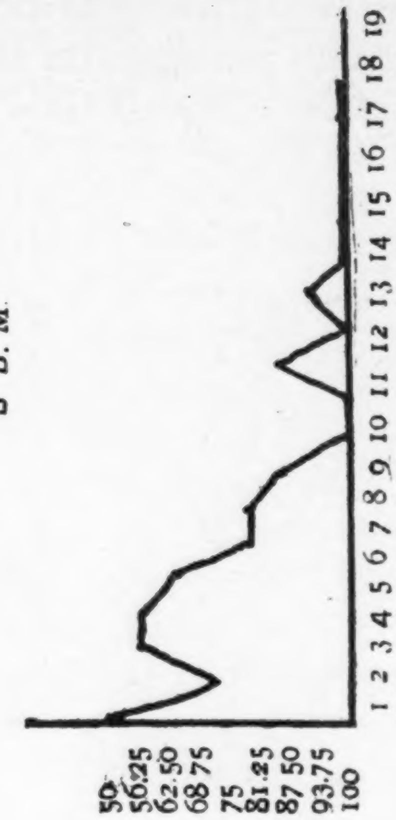


Curve III.

B. F

Curve II.

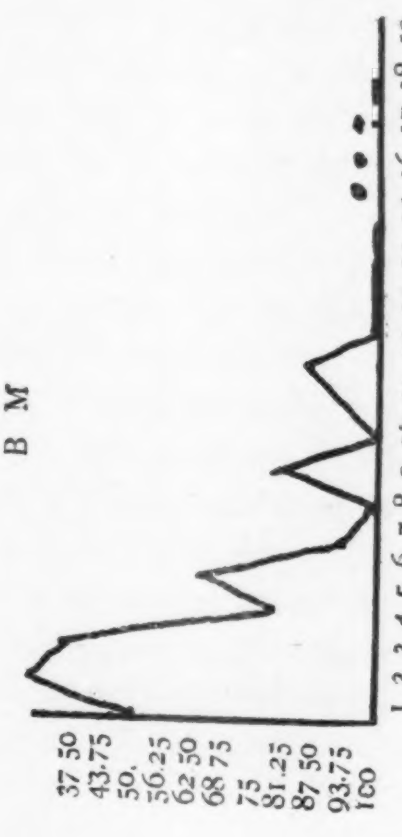
B. B. M.



Curve IV

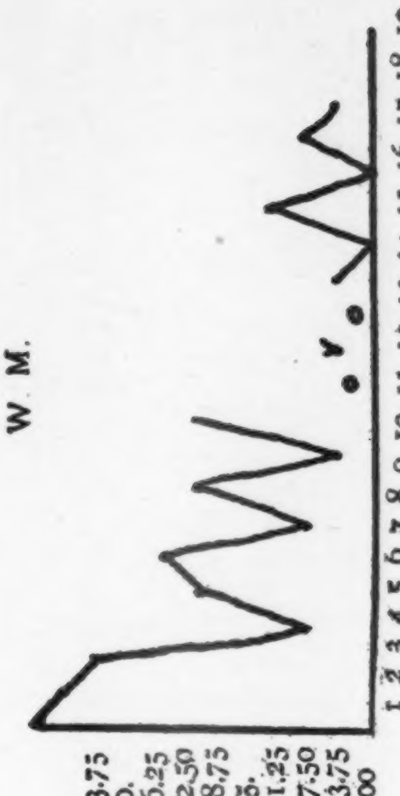
Ordinates = % of error
Abscissae = days.

B M



Curve V.

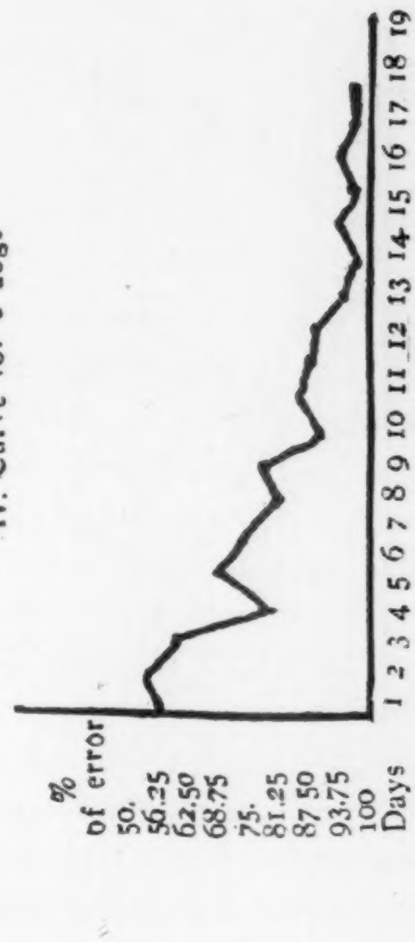
W. M.



Curve VI

o = Refused to run

Av. Curve for 6 dogs



Curve VII.

FIGURE 3

Table II

	Successions on L	R	Alterations L to R	R to L
		First Day		
BTF	11	0	2	2
BrF	4	5	3	3
BF	11	1	1	2
BBM	3	2	5	5
BM	0	9	3	3
WM	7	2	2	4
		Second Day		
BTF	12	1	1	1
BrF	7	2	3	3
BF	8	2	3	2
BBM	2	6	3	4
BM	3	4	4	4
WM	8	1	3	3
		Third Day		
BTF	9	0	3	3
BrF	3	4	4	4
BF	13	0	1	1
BBM	2	6	3	4
BM	14	0	1	0
WM	7	0	4	4

Learning to Discriminate

In learning a series, the behavior is modified, not by success in general, but by each particular success or failure. The evidence for discrimination consists in the integration of a series of acts in a definite order (when the order of presentation of stimuli is constant) and in the variation of this order (when the order of presentation is varied). The problem here is not so much to determine whether the animal does discriminate, as to determine the particular conditions under which this modification of behavior occurs, to note how rapidly the dogs respond to the success or failure to obtain reward, and to note the type of behavior which follows each particular success or failure. The following table shows the complexity of the progress, for the dog BTF. In the first group of columns are shown the numbers of cases in which a successful choice on the left led to a successful "succession," and to a successful "alternation" to the right; also the choices successful on the right which were followed by a successful choice by "succession" or "alternation." (S = "succession"; lAr = "alternation" from left to right; rAl = "alternation" from right to left.) The second group shows the choices which were successful by means of "suc-

cessions" and "alternations," when the preceding choice was unsuccessful. The third group shows the unsuccessful behavior which followed a successful choice. The fourth group shows the figures for unsuccessful behavior when the preceding choice was unsuccessful.

TABLE III
Dog BTF

Day of Series	Successful followed by Successful				Unsuccessful followed by Successful				Successful followed by Unsuccessful				Unsuccessful followed by Unsuccessful			
	L		R		L		R		L		R		L		R	
	S	lAr	S	rAl	S	lAr	S	rAl	S	lAr	S	rAl	S	lAr	S	rAl
1	3	2	0	1	4	0	0	0	2	0	0	1	2	0	0	0
2	3	1	1	1	4	0	0	0	3	0	0	0	2	0	0	0
3	3	3	0	1	4	0	0	0	1	0	0	2	1	0	0	0
4	3	4	3	5	0	0	0	0	0	0	0	0	0	0	0	0
5	3	1	1	4	1	2	0	0	3	0	0	0	0	0	0	0
6	2	3	1	2	3	0	0	0	0	1	0	2	0	0	0	1
7	1	3	2	4	0	1	0	1	1	1	1	0	0	0	0	0
8	3	2	2	4	1	1	0	0	2	0	0	0	0	0	0	0
9	3	3	2	3	1	1	0	0	2	0	0	0	0	0	0	0
10	2	4	3	4	0	0	0	1	0	0	0	1	0	0	0	0
11	2	4	3	4	0	0	0	1	0	0	1	0	0	0	0	0
12	3	3	3	4	1	0	0	0	1	0	0	0	0	0	0	0
13	3	4	3	5	0	0	0	0	0	0	0	0	0	0	0	0
14	3	4	3	5	0	0	0	0	0	0	0	0	0	0	0	0
15	3	4	3	5	0	0	0	0	0	0	0	0	0	0	0	0
16	3	4	3	5	0	0	0	0	0	0	0	0	0	0	0	0
17	2	3	3	5	0	0	1	0	0	1	0	0	0	0	0	0
18	3	4	3	5	0	0	0	0	0	0	0	0	0	0	0	0
19	3	4	3	5	0	0	0	0	0	0	0	0	0	0	0	0
	51	60	42	72	15	5	1	3	15	3	2	6	5	0	0	1

This table shows also the progress of integration. There is a gradual concentration of the figures under the "Successful to Successful" column, and a gradual diminution of the figures in the other columns, with sporadic lapses. The table shows in some detail that this progress is accomplished by elimination of a certain number of reactions under one type of behavior, the substitution of the other type of behavior for it, and at the same time the ordering of the precise sequences according to the established order of stimulus presentation. The behavior thereupon must be considered, not merely behavior, but behavior with regard to a discriminated object, or sign.

Similar tables have been prepared for each dog, but as will appear from our summary of the problem and difficulties, there

are good reasons for omitting them at this time. The purpose of including the above table is to indicate the method of presenting the results which will show the complexity of the process of integration of behavior which is necessary as a criterion of discrimination. By means of this table the elimination of unsuccessful "successions" and "alternations" and the points at which one type is substituted for another are shown. Taken in conjunction with the following Table IV, which shows the days on which each error occurred, an exhibit of the detailed behavior is given which retains the relation of each choice to the integrated behavior. This is valuable for psychological purposes.

Was the integration of the behavior of equal difficulty throughout, or were there points in the series which required a longer time to master? The following table shows, for the same dog, BTF, that the first choice was mastered at the fourth day, and no errors were made thereafter. The same is true of the second choice. On the third choice an error occurred on the 7th day, etc.

TABLE IV

Choice	Dog	Days on which errors occurred	R	L	Total
1	BTF	1, 2, 3	3	0	3
2		1, 2, 3	3	0	3
3		7	0	1	1
4		17	0	1	1
5		1, 2, 3, 5, 12	5	0	5
6		10, 15	0	2	2
7		9	0	1	1
8		2, 6, 8, 9, 13	5	0	5
9		0	0	0	0
10		1, 2, 5, 7, 8	5	0	5
11		1, 2, 3, 6, 9	5	0	5
12		12	0	1	1
13		5	1	0	1
14		1, 3, 6	3	0	3
15		11	0	1	1
16		7	0	1	1
			30	8	38

The table shows further the relative difficulty of the integration of the various acts of choice. If a line were drawn connecting the final one of the days on which errors occurred, it will roughly indicate the relative difficulty of each choice in the series for the dog BTF. It also shows that notwithstanding the

alternating habit which preceded the series, a preference or position error persisted and is shown predominantly on the 5th, 8th, 10th, 11th choices in the series. Grouping by fours the 38 errors which this dog made in establishing this integration, it will be seen that the large proportion of the errors occurred in the middle of the series.

Errors on the	R	L	Total
1st 4	6	2	8
2nd 4	10	3	13
3rd 4	10	1	11
4th 4	4	2	6
			38

Another difficulty which is apparent is that of *retention*. For the first six days the third choice was properly integrated, on the seventh there was a slip at this choice. For sixteen days the appropriate type of behavior was called out on the fourth choice and during the nine days previous there had been no errors on the first four choices. On the seventeenth day, an error was made on this choice. Summing the errors for each choice, for the entire group of dogs we have the following Table V. (S = "succession, A = "alternation.")

TABLE V

Choice 1	18	errors	Choice 11	29	S
2	23	S	12	7	A
3	15	A	13	16	A
4	18	S	14	19	S
5	34	A	15	11	A
6	15	A	16	16	S
7	14	S		284	
8	18	A			
9	5	A			
10	26	A			

Of 284 errors made by the group, 136 occurred on the first and last four choices, 148 on the second and third four choices, bearing out the former statement that the middle of the series is more difficult. This may be taken as additional evidence that the alternating habit is not carried over, since in the first and last group of four, there are four "successions" and three "alternations" and here a smaller number of errors was made than in the second and third groups of four in which there were two "suc-

cessions" and six "alternations." (These figures of course include the 18 errors made upon the first choice.) "Successions" led to 119 errors, an average of 19 5-6 for each choice; and "alternations" led to 147 errors, an average of 16 1-3 for each choice.

By way of summary of the results so far, it may be said that the apparatus described here admits of maniuplation from outside a room; that dogs can be trained to work within the room without the presence of the experimenter; that a training series of the kind described is favored as an equalizer of various species of animals; that this places the animals on a basis with reference to the experiment differing only in degree from that of the human subject whose language is behavior. As a result of the first series of this experiment it is shown that the alternating habit is not transferred to the situation which, so far as the experimenter can control it, remains the same except for the position and intensity of the light; that a study of behavior demands behavior terms and the terms "succession" and "alternation" are suggested as descriptive of the behavior of the dogs in this experiment; that a position error was developed but did not persist longer than three days; that the original behavior in this series was modified by the experience of the animals and the problem is to determine the conditions under which this modification occurs. Lack of retention is shown to be a source of difficulty. A series of 16 successive choices to be made according to an established order is shown to be of unequal difficulty in its various parts. Psychological study demands a mode of presentation of results which shall avoid vague general statistical summaries and get closer to the facts and a step in this direction is indicated by the tables. And finally it is proposed to define discrimination in behaviorist terms. The series of acts of choice which constitute the day's run may be thought of as a whole or as parts. The evidence for discrimination is to be looked for in the integration of the parts into a whole, with reference to some stimulus, which has become gradually organized as the representative of a particular mode of behavior.

Test of Persistence

At the close of Series 3, to be mentioned later, the apparatus was arranged for a repetition of the above conditions to test the persistence of the association set up. Twenty-two days had elapsed. All dogs followed the light, except BrF, who went once to the side on which no light was shown. On the second day, all dogs went to the light, except BM who went once to the dark alley. The third day all choices were correct. On the fourth day, the lights were shown in a new order: B, A, B, B, B, B, B, A, A, A, B, B, A, B, A, A. All dogs correctly followed this new order. We have here a new mode of behavior not the "successions" and "alternations" learned in a certain rigid order. The behavior has become flexible and is freed from the rigidity of the simple reflex. Something is selected and this selectivity is of a type which is the product of experience and fits only under the concept of discrimination.

Second Series

The second stage of the experiment required a similar discrimination between "two-lights-with-food" in one alley as against "one-light-without-food" in the opposite alley. The order of presentation of the two lights was the same as in the first series, viz., B, B, A, A, B, A, A, B, A, B, B, A, B, B, A, A,—16 choices. The series ran for nine days without appreciable change in the level of the curve showing percentage of error. BF became frightened at her image in the mirror during the first day and was dropped from the experiment. The results show that the dogs all started in with an excess of "successions" and that the general tendency was toward an excess of "alternations." The dog, BTF, on the first day made 10 "successions" and 5 "alternations," of which 7 and 3 respectively were successful. On the ninth day she made 3 "successions" and 12 "alternations" of which 1 and 8 respectively were successful. Having been guided at this time by percentage of error curves which concealed the true integration which was slowly going on, I closed the series and began a third series.

Third Series

In the third series "four-lights-with-food" as against "one-light-without-food" were used; and the order in which these were presented was twice in succession in the right alley, then twice in succession in the left alley. During the first four days, the dogs were permitted to run into the apparatus with the four lights showing and the other alley closed. This was designed to emphasize the four lights and to break up the tendency to "alternations" which had appeared in the second series. In the third series the curve of percentage of error remained level. There was constant fluctuation as to number and order of "successions" and alternations," but these varied from day to day and were not retained as permanent members of a growing complex. Such a fluctuation perhaps represents roughly the clawing and scrambling of animals in the problem box; or of running into blind alleys in the maze. But the retention of one type of behavior and the elimination of unsuccessful behaviors failed to occur. There was a failure to pick up a cue which might become organized as the focal point of a complex of elementary acts. The series ran for ten days (160 choices for each dog). In the second and third series together (more than 300 choices) the difference in magnitude of light area (or in intensity of illumination, or in the number of lights) distinguished the two alleys. That this situation is very different for the dog, from the discrimination of a lighted from a dark alley, is at once clear. There is again a failure to transfer a habit from the first series to the following two. It is quite possible that a prolongation of the series might succeed in setting up the association, but the testing of the method was of greater concern at this time.

Final Series

In the final series, "four-lights-with-food" were shown in one alley as against "one-light-without-food" in the opposite alley. The order of presentation was the same from day to day, except that on one day the series began on the right, the following day on the left. The curve of percentage of error for WM is typical (Fig. 4). The series ran for 20 days (320 choices for each dog)

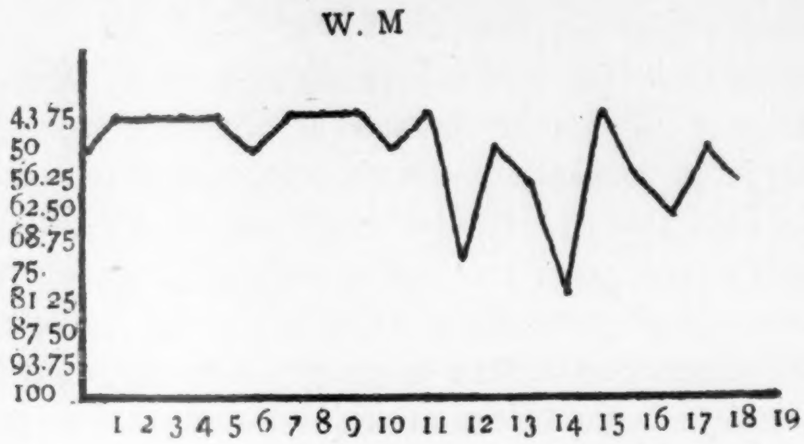
and the accuracy varies between 50% and 81.25%. The accuracy varies little from that of the preceding series in which the first choice for each day was to be made on the same side.

Although the accuracy of choice approaches that attained by the dogs of Hunter (5), the tables of analysis of behavior show clearly that no progress was being made and therefore there is no indication of discrimination. The following Table VI for the dog BBM shows the failure to progress in the distribution of the "successions" and "alternations" toward an expected standard; and that while there was substitution of "successions" for "alternations" and vice versa, from day to day, there was no retention of the modifications.

TABLE VI
Dog BBM

Day of Series	Successful to Successful					Successful to Unsuccessful					Unsuccessful to Successful					Unsuccessful to Unsuccessful				
	L		R			L		R			L		R			L		R		
	S	lAr	S	rAl		S	lAr	S	rAl		S	lAr	S	rAl		S	lAr	S	rAl	
1	0	0	3	4	7	0	1	2	0	3	0	4	0	0	4	0	0	0	1	1
2	0	4	1	0	5	0	0	0	4	4	0	0	1	3	4	0	2	0	0	2
3	1	3	1	1	6	1	0	1	2	4	0	1	0	3	4	0	1	0	0	1
4	0	3	0	0	3	0	0	0	4	4	0	0	0	0	4	0	4	0	0	4
5	0	3	1	1	5	0	0	1	3	4	0	1	0	3	4	0	2	0	0	2
6	0	3	0	0	3	0	0	0	4	4	0	0	0	4	4	0	4	0	0	4
7	1	1	2	1	5	2	0	3	0	5	0	3	0	2	5	0	0	0	0	0
8	0	2	0	0	2	0	0	0	4	4	1	0	0	3	4	1	4	0	0	5
9	2	4	0	0	6	1	0	0	2	3	0	0	0	4	4	0	2	0	0	2
10	0	1	1	2	4	1	1	2	1	5	0	3	0	2	5	0	1	0	0	1
11	2	2	1	2	7	0	1	0	1	2	1	1	0	1	3	1	1	0	1	3
12	0	2	0	0	2	0	0	1	3	4	0	0	0	0	4	0	4	1	0	5
13	0	1	3	2	6	0	0	3	1	4	0	2	0	1	3	0	1	1	0	2
14	0	1	2	3	6	0	1	1	1	3	0	3	0	1	4	0	1	0	1	2
15	0	2	0	0	2	0	1	1	2	4	0	1	1	3	5	0	2	1	1	4
16	0	1	2	2	5	0	1	1	2	4	0	2	1	1	4	0	1	0	1	2
17	2	3	2	3	10	0	1	0	1	2	0	1	0	1	2	0	0	0	1	1
18	0	1	1	1	3	0	0	2	2	4	0	1	0	3	4	0	3	1	0	4
19	0	2	2	2	6	0	1	1	2	4	0	2	1	1	4	0	0	0	1	1
20	0	2	2	2	6	0	0	1	2	3	0	2	0	2	4	0	2	0	0	2
	8	41	25	26		5	8	20	41		2	27	4	46		2	35	4	7	

The total percentage of errors for the final series is approximately the same as for the second and third. It is considerably more than 50%. This was an unexpected result since the change in the location of the beginning choice for each day would supposedly prevent the record from showing so high a percentage.



Curve XXIII
FIGURE 4

The only conclusion which can be drawn regarding discrimination here is that, for the conditions of this experiment, the difference between four lights and one light is too small a difference upon which to organize and control the reactions.

Attention should be called however to the fact that the reactions occurred—perhaps in response to the total situation or to some part of the situation the nature of which is unknown—in such a way as to force the recognition of the underlying organic activity of the animals. The raw material, so to speak, is present; the influence of the preliminary training series is not shown in the specific mode of behavior, yet is shown in the continuation of activity in a dark experimental room without the presence of the experimenter. Something has been carried over from the preliminary training series to the later experimental series which is not to be seen in the tables of results, but might be described as a "general set" toward experimental situation. Considering the difficulties of manufacturers to secure continued work from human beings unwatched, especially in new countries, it is worthy of note that the dogs will readily assume a "work" habit which leads them through a complicated apparatus day after day without immediate supervision.

It is hoped that this experiment may be repeated under conditions more satisfactory for final conclusions.

REFERENCES

1. Colvin, S. S., and Burford, C. C. The color perception of three dogs, a cat and a squirrel. *Psychol. Rev., Monog. Suppl.,* 1909, **11**, 1.
2. Franken, A. Instinkt und Intelligenz eines Hundes. *Zsch. f. angew. Psychol.,* 1911, **4**, 1 and 399.
3. Hicks, V. L., and Carr, H. A. Human reactions in the maze. *J. of Animal Behav.,* 1912, **2**, 103.
4. Hoge, M. A., and Stocking, R. J. A note on the relative value of punishment and reward as motives. *J. of Animal Behav.,* 1912, **2**, 43.
5. Hunter, W. S. The delayed reaction in animals and children. *Behav. Monog.,* 1913, No. 6.
6. Johnson, H. M. Audition and habit formation in the dog. *Behav. Monog.,* 1913, No. 8.
7. Smith, E. M. Color vision in dogs. *Brit. J. of Psychol.,* 1912-13, **5**, 1.
8. Thorndike, E. L. *Animal Intelligence.* New York: Macmillan, 1911.
9. Washburn, M. F. *The Animal Mind.* New York: Macmillan, 1909.
10. Weidensall, C. J. A critique of the discrimination test: A study in animal behavior. *Psychol. Bull.,* 1912, **9**, 57.
11. Yerkes, R. M. *The Dancing Mouse.* New York: Macmillan, 1907.
12. Yerkes, R. M. The role of the experimenter in comparative psychology. *J. of Animal Behav.,* 1915, **5**, 258.

AN EXPERIMENTAL STUDY OF MENTAL CAPACITIES OF SCHOOL CHILDREN, CORRELATED WITH SOCIAL STATUS[1]

Horace Bidwell English, Ph.D.
Instructor in Psychology
Wellesley College

Thirty-seven children, thoroughly representative of the professional and upper middle class of England were tested and compared with thirty-one children equally representative of the lower middle class and the better class of tradesmen. There were ten tests measuring, with varying degrees of satisfactoriness, the functions of memory in its various forms; perceptual discrimination; analogical reasoning; rapidity of arm-movement; rapidity and accuracy of arm-movement under conditions demanding maximal attention; ability to divide attention or rapidly to alternate it; ability to understand spatial relations or to introduce order into one's spatial perception; and ability to comprehend conceptual relations.

In all save the tests of rapid movement, the children of the "better class" were strikingly superior.

Contents

[1] The writer wishes to acknowledge his great indebtedness to Professor Wm. McDougall for constant help and encouragement throughout the progress of the investigation. Dr. Edgar Schuster helped in devising the tests and in various other ways. Miss M. Smith of Cherwell Hall, Oxford, was of great assistance in correlation work. The Headmasters of the three schools were most courteous in giving their aid. And finally, he had throughout in applying the tests the invaluable assistance of Miss M. Bickersteth.

The investigation was carried out in Oxford, but this report was written, with critical editing by Professor Angier, while the writer was serving (1914-1916) as assistant in the Yale Psychological Laboratory.

I. Aim of Investigation and Selection of Tests

What empirical differences in respect to intelligence can one find between children of different social strata? Is it possible to demonstrate that these differences are hereditary or to establish a strong presumption to that effect based on empirical evidence? The investigation here reported will, it is hoped, add a little more towards the solution of these long-mooted problems. This was constantly before us as our principal aim. At the same time it was our hope that we might also add to the rapidly growing test literature some evidence as to the nature and value of various tests, some of them new. For this reason, correlations between test and test and between tests and general intelligence were calculated.

During the spring and early summer of 1913, Dr. Schuster, Professor McDougall and the writer met frequently to devise and try out tests suitable for our purposes. Several undergraduates volunteered to act as subjects. In the fall of the same year, Miss Bickersteth and the writer tried them out on a slightly larger scale with twenty-six boys at the parish school of St. Phillip and St. James. We were thus able pretty thoroughly to sift the tests and to standardize our technique before we began in 1914 the tests below described, in the Oxford Central Elementary School and the Oxford Preparatory School.[2]

A final consideration of the suitability for our purposes of the tests chosen must be deferred until we have studied the results of each in detail. At this point it is in place, however, to state the general principles which guided us in our search for tests.

(1) Independence of the *general* conditions of school and home training. This is necessary if we are to test for mental inheritance; and the degree of this independence (which is confessedly difficult to determine) is the measure of the test's value. (But see p. 328 ff. for a fuller discussion.) This consideration led to the rejection, for example, of the "Size of Vocabulary" test,

[2] In England a "Preparatory School" trains boys from 8 to 14 for entrance into the great "Public Schools." It is, of course, a private institution, generally with boarders.

which has a high correlation with intelligence but is obviously too dependent upon home and school influences.

(2) Exact objective measurement.

(3) Reliability. A test is reliable when its result is not determined to any great degree by changing and momentary conditions.

(4) Freedom from complicated apparatus.

(5) Exact quantitative formulation. For anything like detailed comparison between two groups, it must be possible to express quantitatively in a single figure the ability of each subject in a given test. This excludes not only all tests with a simple "yes" or "no" answer, but all simple alternative tests where the grading is either "plus" or "minus," "right" or "wrong."

One or another of these criteria excludes practically every test of the Binet-Simon series. Most of these permit of no fine gradations and their dependence on accident, environment, and training is often marked.

In the following pages, tests have been given shortened and more or less cryptic names for convenience of reference. It is hoped, however, that these names give sufficient clue to the nature of the test when once explained. In the list that follows the column headed "Nature of Function Tested" must be taken as schematic and provisional. Each of these tests will be described later in detail. The ten tests, Nos. 2 to 11, are those with which we are chiefly concerned.

Name of Test	Nature of Function Tested
1. "Plunger"	Quickness and accuracy of movement
Alphabet Tests:	
2. "Letters" 3. "Figures"	Quickness of perceptual discrimination
4. "Alternating"	Quickness of perceptual discrimination and ability to distribute attention
5. "Tapping"	Rapidity of movement and ability to sustain effort
6. "Analogies"	Reasoning
7. "Dotting"	Accuracy and quickness of movement and quickness of practical judgment
8. "Spot Pattern"	Range of visual attention and ability to apprehend spatial relationships
9. "Related Memory"	Memory for words having sense connection
10. "Narrative Memory"	Memory for prose narrative
11. "Immediate Memory"	Memory for unconnected words
Discs and Circles Tests:	
12. "Disc Sorting"	Manual dexterity, accuracy of practical judgment based on peripheral vision
13. "Circle Judging"	Speed and accuracy of discrimination-judgment (perceptual)
14. "Combined Discs and Circles"	As for 12 and 13, and ability to distribute attention

II. Children Investigated

Opportunity was given us to work with two groups of subjects admirably suited for our purpose—children old enough (from 12 to 14 years) to understand and grapple with fairly difficult tasks, but young enough not to have their innate endowment too much concealed by habit. On the other hand, respective socially homogeneous groups were desired. Both these requirements we found in two Oxford schools.

The Central School is a fee-paying, elementary school, drawing its pupils from the lower middle classes. The parents are small tradesmen, artisans, and college servants—presumably on the whole neither defective nor preeminent in ability. Such a school receives practically no very poor boys and it is a fair assumption that all are well nourished. Nevertheless, several boys falling within the age limits were dropped because their obviously defective physique precluded their doing effective mental work. Those left were, therefore, a little above the average of the school in physical fitness.

The parents of the Preparatory School boys are mostly persons occupying high posts in the ecclesiastical, civil or academic world. So many of the boys are sons of Oxford "dons" that the list of names sounds like the roll of the Oxford professoriate. Such posts imply eminence in ability and culture. The entire class represented is, in England at least, the result of a long process of social and professional selection. Here if anywhere we should expect to find preeminent ability inherited. These Preparatory School boys will be called hereafter in this paper Group A and those of the Central School, Group B. These two schools are the same in which Burt (2) carried on his experiments in 1908.

Table I gives the most important figures in regard to height, weight, and age.

TABLE I

	Maximum	Minimum	Median	Average
		Height in inches		
Group A	63.25	56.75	58.75	59.97
Group B	64.14	52.25	57.75	57.57
		Weight in pounds		
Group A	127.5	68.5	84.	87.7
Group B	117.5	56.75	77.5	79.73
		Age in years and months		
Group A	13— 9	21— 0	12— 0	12—9.97
Group B	13—11	11— 8	13— 0	12—10.5

It will be observed that the youngest subject in Group B falls outside the limits fixed. First included by mistake, he proved so good a subject that he was retained. He was placed 12th on the tests as a whole. The omission of his marks would, therefore, slightly decrease the averages of Group B. It will also be noticed that Group A boys were slightly heavier. Probably this was an indication of somewhat superior health.

III. Application of Tests

Both Miss Bickersteth and the writer carefully practised every test before applying it to the subjects. The instructions to subjects were practically memorized by us and were kept very uniform. Great stress was laid on this point. Whenever it seemed that a subject was not doing his best, an effort was made to stimulate him to his optimum. The interest and rivalry at Group

A school rendered this seldom necessary. On the other hand, the competitive spirit even when stimulated by the offer of a prize was comparatively weak at Group B school. The boys seemed to be trying to do their best because they were told to, and to have, very often, no interest in comparative results. This whole question of interest and motive will be dealt with later. Every effort was made to put the subjects at their ease and there is no doubt that they soon became accustomed to the experimenters and the tests. The "plunger" test was retained as the first test in order to absorb initial nervousness, although it was soon obvious that the results from the test would be, for any other purpose, useless.

Unless otherwise stated, subjects were tested one at a time. According to their length, one, two or three tests were given at each sitting. From 15 to 30 minutes was the usual duration of a sitting, the latter time being never materially exceeded. In every case, the subjects were encouraged to ask questions in order to insure a proper understanding of the task. Each test was given twice to each subject. In nearly every case the writer gave it first while Miss Bickersteth assisted on the repetition. When she tested first, the writer usually gave the repetition. Since we had worked out our procedure together at St. Phillip's School, it was thought that it would make little difference which experimenter conducted the test. (But see p. 308 note, for a discussion of this point.) The interval between first and second trials varied somewhat for different tests and according to the exigencies of school work, but was kept approximately the same for the two schools. The interval will be stated in connection with the description of each test. All tests were conducted in the morning—i. e., before the mid-day meal. Any necessary time measurements were made with a stop-watch recording fifths of a second.

IV. Methods of Treating Results

Correlations.—The correlations meant are those between test and test and between tests and general intelligence. These are not only of very great intrinsic interest but they are very useful

in establishing the value of a test and in analyzing the functions tested. The subjects were arranged in ranks according to their achievements in each test and correlations were calculated by the Pearson "Product-Moment Method" adapted to ranks, the formula for which is:

$$r=2\sin\left(\frac{\Pi}{6}\left[1-\frac{6S(\nu_1-\nu_2)^2}{n(n^2-1)}\right]\right)$$

The probable error of this formula is $\frac{.7063\,(1-r^2)}{\sqrt{n-1}}$. **(5)**

The conception of "partial" or "multiple" correlation is one of very great importance, and one we shall use occasionally to assist us in our analysis of certain tests. A "partial" correlation is the value of a correlation between two variables, 1 and 2, for constant values of 3, 4———n. If there are 3 variables, the equation is $r_{12\cdot3}=\frac{r_{12}-r_{13}r_{23}}{\sqrt{1-r_{13}^2}\sqrt{1-r_{23}^2}}$ where the subscripts indicate the variables correlated. The subscripts 1 and 2 preceding the point in $r_{12.3}$ are the variables whose correlation is sought for a constant value of the variable following the point. (1, p. 63.)

"Reliability" coefficients are simply the correlations between two applications of one test. Brown (1, p. 86) suggests that they be called the "coefficients of *individual* correlation." They indicate the tendency of the individuals comprising the group to deviate from their own (individual) hypothetical mean. Hence they measure to a large extent the interference of those accidental disturbing factors which cause deviation from this hypothetical mean.

All our correlations are what Spearman (**8**) calls "uncorrected" coefficients. For while the need of "correction" is recognized, it cannot be said that Professor Spearman's formula for correction has established itself (cf. Brown, 1, p. 83 ff.).

We shall later have to try to account for the differences shown in the relative correlations between tests at the two schools—a test may show a fairly high correlation with a certain other at one school, practically none at the other school. To anticipate somewhat, one may say here that we are not always successful in this attempt at explanation. It is well to bear in mind, how-

ever, that a task may test one function in one person, another function in another. Especially is this true if the persons be of markedly different levels of intelligence. Simpson (7), for example, found very different correlations between tests according to whether he took the "good" group (university professors and graduate students) or the "poor" group (men at a Salvation Army Industrial Rescue Home). It is not surprising therefore if the correlations are not always the same in the two groups.

Measures of general tendency.—The arithmetical mean or average is computed in each group for each test, for its repetition, and for the amalgamation of first and second testings. The median is also indicated in each of these cases, together with best and worst individual achievements. The diagrams accompanying each test require some explanation. Each group was broken up into six divisions or classes, based on proficiency in that test.[3] The average of each division was then taken. This gave the value which determined the position of each class along the axis of the ordinate. Along the abscissae the classes were arranged in order from "worst" to "best." The line connecting the points thus determined is a broken ascending or descending line. With both groups plotted on the same diagram, it is possible to compare the best with the best, the worst with the worst, thus avoiding a familiar error. The angle each segment of the line makes with the abscissa measures the amount of improvement from division to division.[4] To save space the abscissa is drawn through the mean for all subjects, both groups, and not through the zero, which is a point of no significance in this connection. (See, for illustrative curve, Fig. II.)

Averages based on such a small number of subjects as compose these divisions are usually of slight value on account of large "sampling" errors. The members of these divisions were, however, carefully selected according to rank and with such homogeneous groups, the mean is doubtless an adequate measure of tendency.

[3] To make the groups exactly divisible by six, the median was in each case excluded.

[4] The scale is not the same for all the tests, however. Each test can be studied only by itself. In all figures, the dotted line represents Group A, the solid, Group B.

In the regular formula for the standard deviation from the mean (S. D. or $\sigma = \frac{\sqrt{\Sigma (d)^2}}{n}$, *d* being the deviation of any observation from the mean) the calculation of σ is very laborious. Now in the deviations of the means of the several divisions or classes which were used in constructing the diagrams, we have at hand substitutes for the deviations of the individual observations from the mean of the whole group; that is, we treat our divisional means as if they were actual individual observations. Where n is small (as in this case where it becomes uniformly 6) the formula for the standard deviation is usually written $\sigma = \frac{\sqrt{\Sigma (d)^2}}{n-1}$. With this correction made, the index of variability, *s*, obtained by this shorter method, becomes slightly larger than the S. D.[5] Probably the index of variability as calculated by this *s*-method is slightly less reliable than the orthodox S. D. It is sufficiently reliable, however, to serve its purpose in this paper—viz., to afford some sort of indication of the variability of the test and hence of the significance of the mean as a measure of general tendency.[6]

The P. E. of the Mean is $\frac{0.6745\sigma}{\sqrt{n}}$. In all cases, however, we have substituted s for σ. The P. E. of the Mean is the measure of the reliability of M as a measure of general tendency. The chance that the "true" mean differs from the calculated mean by three times the amount of the P. E. is one in twenty-three. To distinguish this P. E. from others, it is called in the tables that follow in this paper the E of M.

An amalgamation of two or more trials is generally more reliable than any single trial. Accordingly in most comparisons the amalgamation of the two testings is used. In not a few

[5] *Cf.* "Letters" test. First testing: $\sigma = 31.4$; by the shorter method, $s = 33.36$. Repetition: $\sigma = 34.56$; by the shorter method $s = 34.87$.

[6] This method of obtaining a measure of variability is not put forward as a general substitute for the S. D. Only when the divisional means are required (as here, for the diagrams) is any very material saving in computation effected. Where sextiles, octiles, etc. are indicated, one may use these to obtain a still easier and still more rough-and-ready measure of variability.

cases, however, the first testing is more significant and it seems best, therefore, to give the results for both testings as well as for the amalgamation. Correlations between tests and between tests and estimations of intelligence are, unless otherwise stated, based on the amalgamation of the two trials. There are two ways of arranging subjects in order of merit upon the basis of two trials: either the times (or other measure of ability) for the two trials, or the place-positions, may be added. The difference in result is small, slightly greater emphasis being laid by the latter method upon the differences between the two trials. As we deemed these differences to have their value, this latter was the method adopted. Correlations are thereby somewhat lessened.

In calculating averages, correlations, etc., the operation was carried to the point where the third decimal place would not be influenced by a change. The third place was dropped (according to the usual rule) only after all operations were concluded. Apparent discrepancies may thus occur. A correlation of .706 may have a probable error of .060; while one of .714 will have a probable error of .054. In the table both appear as .71, one with a probable error of .06, the other with a probable error of .05. The writer was careful to avoid mere arithmetical errors. In using the slide rule, certain inaccuracies may have crept in but he is quite confident that none of these affect the second decimal place.

V. Method of Provisionally Estimating Intelligence[7]

At the Group B school, the Headmaster drew up a list of the boys according to his estimate of their intelligence. His long experience as a teacher, his intimate acquaintance with all the boys and his clear understanding of the problem give one great confidence in the estimate. It must be kept in mind, however, that it is only an *estimate*. The low position given by him to one boy who did very well in the tests reduced very much many correlations with "intelligence." This particular boy impressed

[7] In correlating the results of the several tests with "intelligence," the term "Imputed Intelligence" is used both in the text and in the Table of Correlations.

the writer as being lazy—a quality which does not recommend itself to the pedagogue. The unusual nature of these tests stirred him into activity and showed his capabilities.

It was unfortunately impossible to secure a similar list for Group A. Recourse was had, therefore, to the position of the subjects on the school roll. As the boys were drawn from five forms and as no effort was made to dovetail them together, such a list is evidently an exceedingly poor method of estimating general intelligence. It may be used to confirm the results obtained with the more trustworthy Group B estimate or to lend some little weight to *a priori* expectations. Wherever a test shows a strong correlation with the school roll, we may assume some sort of correlation with intelligence.

VI. Apparatus, Procedure and Results of the Several Tests

1. "Plunger" test

The test was designed to measure quickness and accuracy of movement. A brass plate was fixed firmly upon a solid wooden block. Into this plate were set 30 bronze tubes 1.75 cm. high, 1.09 cm. in diameter. The tops were slightly beveled. A steel plunger set in a handle fitted nicely and easily into any given tube. The subject was instructed to push the plunger to the bottom of each tube in turn as rapidly as possible, holding the plunger more or less like a pen. Three complete rounds were made and time taken. Since the individual differences were very slight, the test was retained merely as a preliminary test in order to absorb the inevitable initial nervousness of some boys.

2, 3, and 4. "Alphabet" tests

(2="Letters" test; 3="Figures" test; 4="Alternating" test.)

In its present form the test is entirely new although it is a development of the alphabet test used by Burt (2). Enlarged replicas of the three parts of Fig. 1, each 9.5 cm. square and each on a separate sheet of paper were provided for every subject. The principle according to which these test sheets were constructed can be better explained after the procedure has been described.

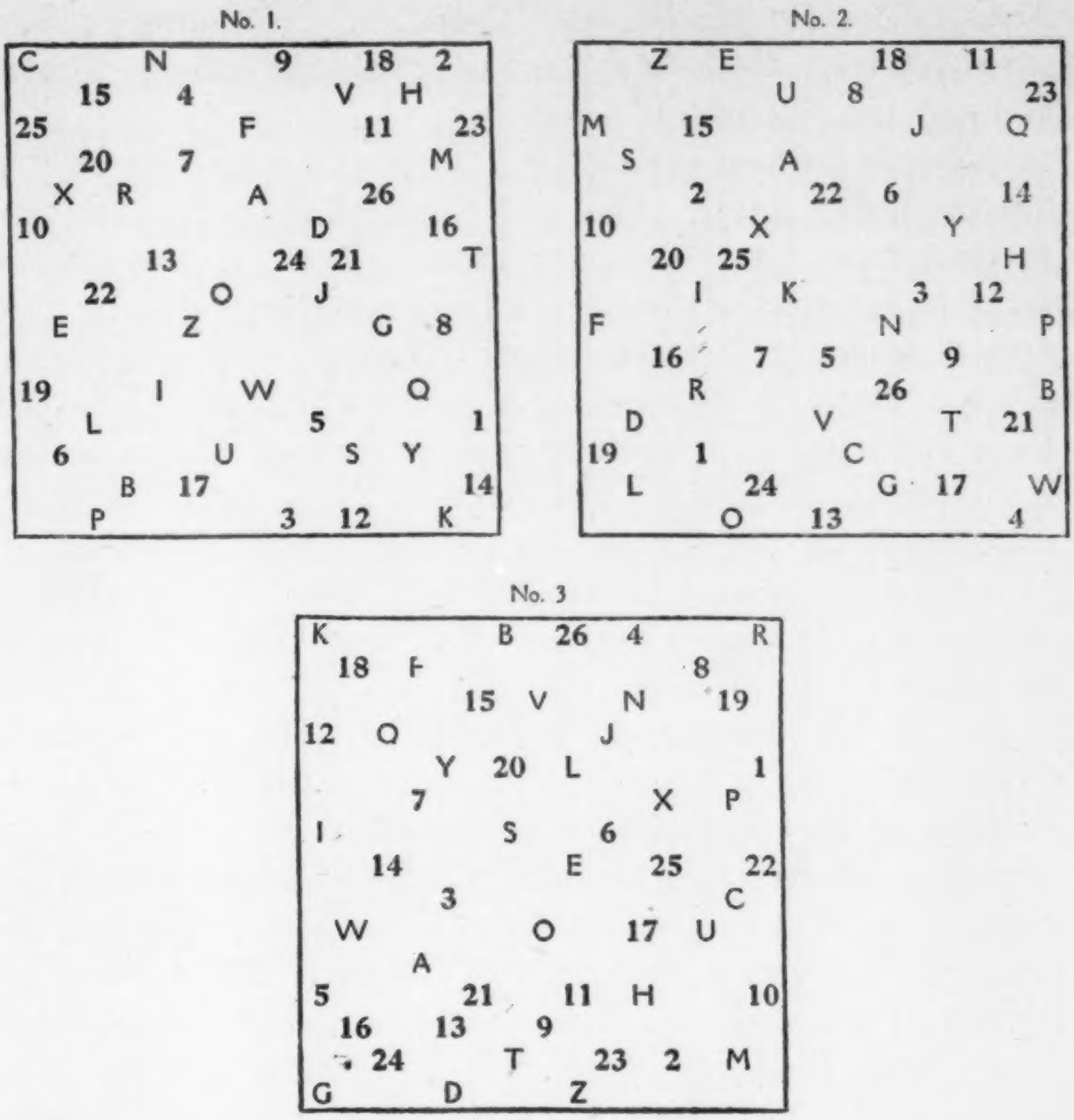


FIG. 1.

The subject was shown sheet No. 3 and the following instructions were given. "I am going to give you a sheet [No. 1] very much like this and I want you to cross off with this pencil the letters of the alphabet in order. This way [illustrating A to D] and so on to Z. Pay no attention to the figures. Call the letters aloud as you cross them off. And do it just as fast as you can. Is that clear? Then ready! Go!" A paper was always kept over the sheet to be used until the word "Go!" The time was recorded with a stop-watch in fifths of a second.

"On the next sheet [No. 2], you are to pay no attention to the *letters* but are to cross off the *figures* from 1 to 26 in *order*.

Notice the difference between 'I' and '1.' [Pointing.] Now see if you can't do the numbers faster than the letters. Ready? Go!" Time recorded as before.

"Now on the next paper [No. 3], I want you to cross off first a letter, then a figure. This way [illustrating on the sheet just finished, from A-1 to D-4] and so on to Z-26. Not two letters and then two numbers but first a letter and then a number. 'A' first, remember! You understand? Then as fast as you can go! Ready? Begin!" By means of a splithand stop-watch time was taken at the halfway point and again at the end. When the test was repeated (after about two months), the order of the papers was altered and the instructions were very much shortened.

The test sheets were constructed as follows. The square was divided into 25 square sections. "A" was located at random. In locating the others, no character was put nearer than two squares in any direction to the letter or figure just preceding or just following it, whether in the order of letters or of figures alone or of the two alternating. An effort was made to avoid putting successive characters on the same horizontal lines, especially from left to right, but this was not always possible, the preceding convention limiting very severely the number of squares in which the characters could be placed. Constructed in this way, sequences of any sort are avoided and the three pages are of almost exactly the same difficulty and may be upon occasion interchanged—as, for example, when false starts are made.

As for the results, the coefficients of reliability in Group A are $.309 \pm .105$, $.261 \pm .108$, $.698 \pm .06$, for "Letters," "Figures" and "Alternating Letters and Figures" respectively.[8] In Group B the same coefficients were $.565 \pm .088$, $.71 \pm .064$, $.778 \pm .052$. The lowest reliability coefficient is thus considerably more than twice its P. E.

The correlations of the various parts of this test with other tests may be seen by reference to the table of correlations (Table

[8] It is convenient to indicate the probable error of a correlation index by writing the index plus or minus the probable error. A good correlation should be at least twice, and in any doubtful case, at least three times its probable error.

XVI). The only noteworthy point is the fairly high correlation of "Letters" and "Alternating" with the "Analogies" test while the "Figures," despite its high correlation with "Letters" and "Alternating," shows no correlation with "Analogies" at all. That this is the case in both groups would indicate that it is hardly an accident. Moreover the probable error of the differences between the correlation "Figures-Analogies" on the one hand and "Letters-Analogies" on the other was determined. The formula for this is $P.\,E._{a-b} = \sqrt{P.\,E_a^2 + P.\,E_b^2}$. The differences and their errors in the above cases are: Group B, .316 ± .117 and .306 ± .17; Group A, .187 ± .16 and .279 ± .155. As the differences are thus materially larger than their probable errors, they can scarce be accidental. Just what quality the "Figures" test lacks and the other two possess, which is the ground of the correlation with the "Analogies," it is not easy to suggest.

In Group A only the "Figures" show a tendency to correlate with age but in Group B the tendency is quite pronounced in all three divisions of the test. This is probably attributable to the fact that the younger subjects in this group had not learned to repeat the alphabet or to count as well as its older members. At the Group A school even the youngest members seem to have been drilled in these two processes as well as, or even better than, the older subjects.

All three divisions of this test show substantial correlations with "Imputed Intelligence" in both groups.

Turning now to the performances, we find the superiority of Group A quite marked at every point (Curves, Figs. II, III, IV). The superiority is particularly marked among the poorer subjects, the best subjects of Group B not falling quite so noticeably behind those of Group A. Tables II, III, IV give the more significant figures for each group.

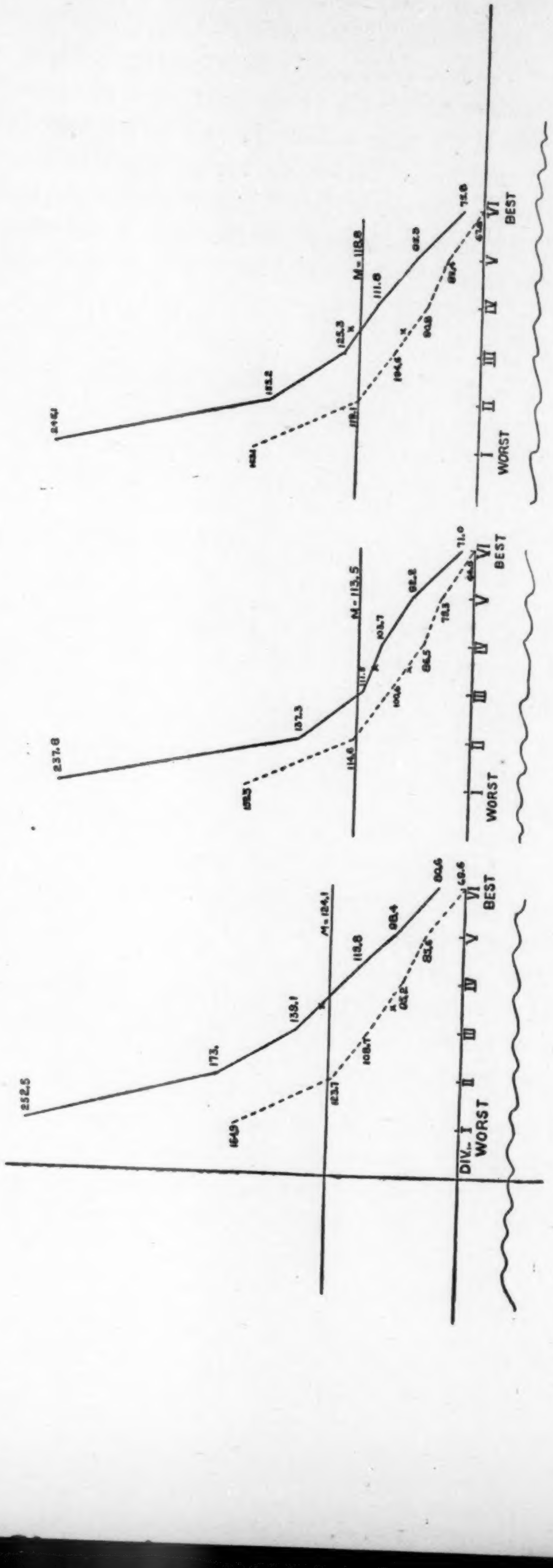


FIG. II.

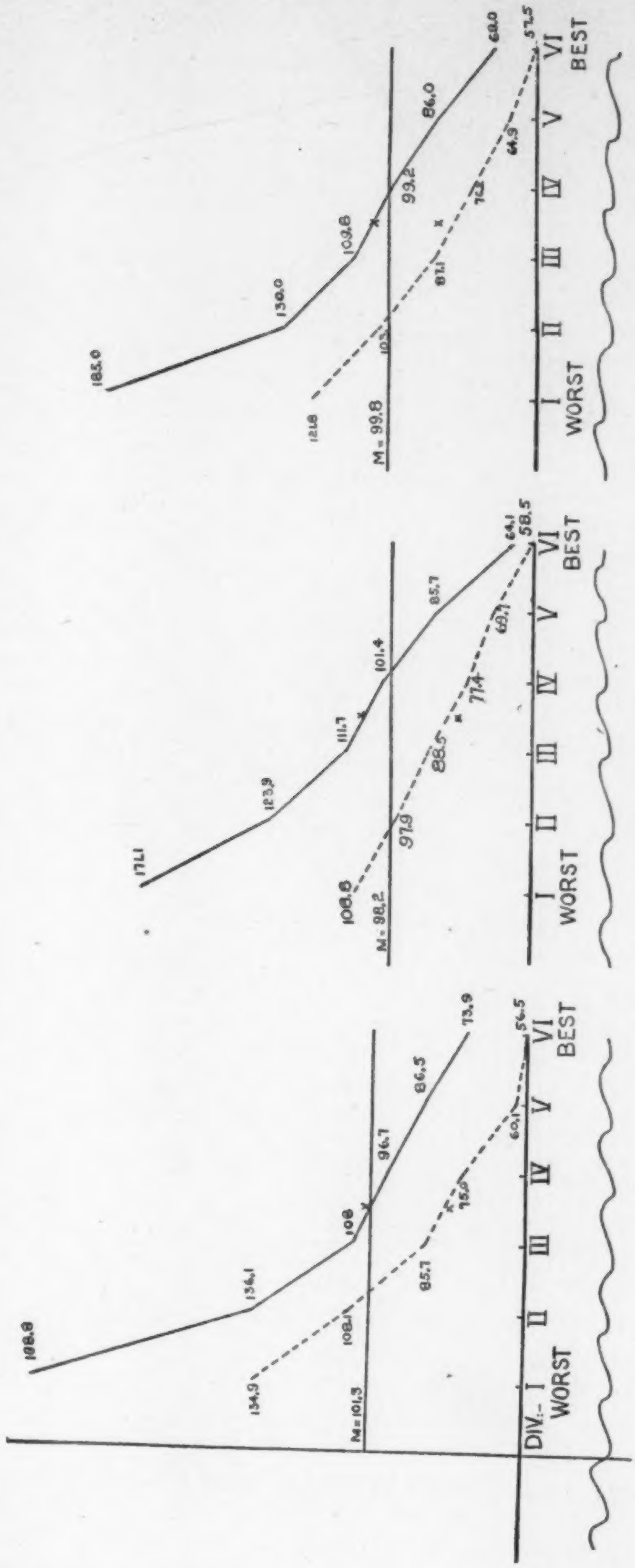
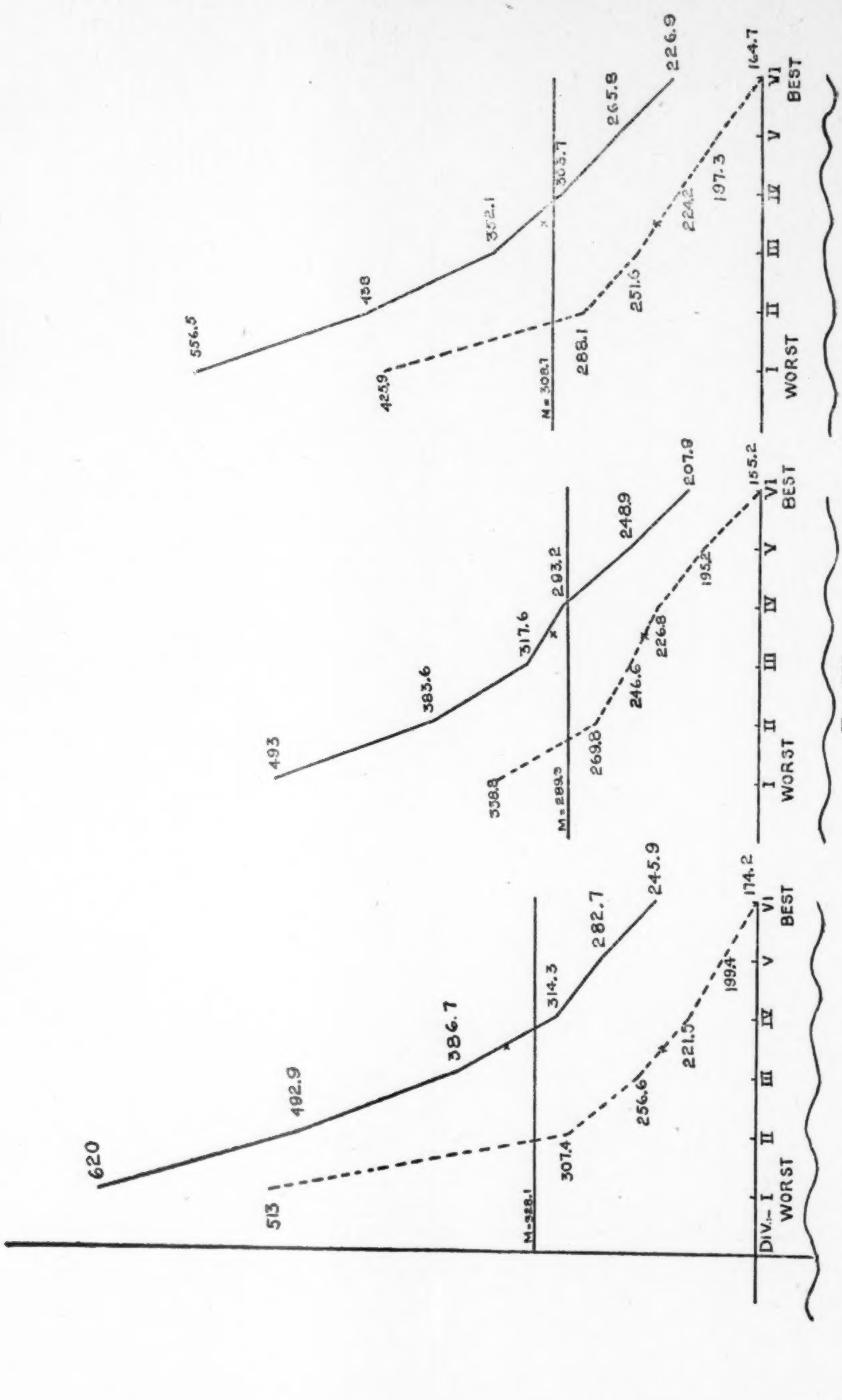


Fig. III



620
492.9
386.7
314.3
282.7
245.9
513
307.4
256.6
221.5
199.4
174.2
M=328.1
DIV.– I II III IV V VI
WORST
BEST
493
383.6
317.6
293.2
248.9
207.9
338.8
269.8
246.6
226.8
195.2
155.2
M=289.3
I II III IV V VI
WORST
BEST
556.5
438
352.1
303.7
265.8
226.9
425.9
288.1
251.6
224.2
197.3
164.7
M=308.1
I II III IV V VI
WORST
BEST

FIG. IV.

TABLE II

"Letters." First Testing. Time in seconds.[8a]

Averages by Divisions[9]	I	II	III	IV	V	VI	Best	Worst	Median	Mean	s	E of M
Group A	164.9	123.7	108.7	95.2	85.6	69.6	52.2	180.8	99.0	107.66	33.36	±3.70
Group B	252.2	173.	139.1	119.8	98.4	80.6	74.8	330.4	128.6	143.7	60.85	±7.37
Second Testing												
Group A	159.3	114.6	100.6	86.5	79.3	66.0	61.4	236.2	92.4	95.08	34.87	±3.87
Group B	237.8	137.3	111.5	103.7	92.2	71.0	63.	386.8	107.	127.19	59.15	±7.16
Amalgamation[10]												
Group A	162.1	119.1	104.6	90.8	82.4	67.8	59.9	173.6	101.	101.37	33.48	±3.71
Group B	245.1	155.2	125.3	111.8	95.3	75.8	69.3	357.6	124.2	135.46	60.41	±7.32

TABLE III

"Figures."[12] First Testing

Averages by Divisions	I	II	III	IV	V	VI	Best	Worst	Median	Mean	s	E of M
Group A	134.9	108.1	85.7	75.	60.1	56.5	46.	165.	78.8	88.36	30.19	±3.35
Group B	198.8	136.1	108.	96.7	86.5	73.9	62.8	249.	103.	116.87	45.47	±5.53
Second Testing												
Group A	108.8	97.9	88.5	77.4	69.7	58.5	44.4	118.4	79.8	83.38	18.57	±2.60
Group B	171.1	123.9	111.7	101.4	85.6	64.1	48.4	207.4	107.6	108.81	38.71	±4.69
Amalgamation												
Group A	121.8	103.	87.1	76.2	64.9	57.5	51.3	118.7	86.	85.87	24.18	±2.68
Group B	185.	130.	109.8	99.2	86.	69.	62.1	202.8	104.6	112.84	41.33	±5.02

TABLE IV

"Alternating."[12] First Testing

Averages by Divisions	I	II	III	IV	V	VI	Best	Worst	Median	Mean	s	E of M
Group A	513.1	307.4	256.6	221.5	199.4	174.2	161.8	690.	239.4	277.29	106.05	±11.76
Group B	620.	492.4	386.7	314.3	282.7	246.	214.8	737.	349.	388.67	101.20	±12.08
Second Testing												
Group A	338.8	269.8	246.6	226.8	195.2	155.2	138.2	391.8	237.6	238.66	64.89	± 7.2
Group B	493.	383.6	317.6	293.2	248.9	207.9	173.8	537.5	300.	328.66	107.16	±13.0
Amalgamation												
Group A	425.9	288.1	251.6	224.2	197.3	164.7	152.2	540.9	240.73	257.96	92.30	±10.24
Group B	556.5	438.	352.1	303.7	265.8	226.9	206.7	602.4	317.3	358.66	122.09	±14.78

[8a] For each mistake, 2 seconds were added to the actual time as penalty. This is certainly sufficient, since the subject was compelled to correct the error at the time as well. Very few mistakes were made.

[9] See page 273 for explanation of the method by which these divisions were made.

[10] Amalgamation. Under this head is given the average of the *subject* who did "Best," "Worst," or "Median," not the average of the two "Best," "Worst" and "Median" *results*. In case of ties (such as would result when subject A is first in one trial, fourth in the other, while B is second in one and third in the other), the mean of the two subjects is given.

[11] See notes to Table II, all of which apply equally to the "Figures."

[12] See notes to Table II, all of which apply here with one exception—

The clear-cut superiority of the Group A subjects may be explained on several grounds. Aside from the specific instructions, subjects were allowed to "gae their ane gait" unless, indeed, it was seen that a subject was fatally handicapping himself by a wrong procedure, and Group A boys showed not only in this, but in practically all tests, a flexibility in adapting themselves to the unusual conditions of the work which was frequently entirely lacking in the other group.[13] This showed itself primarily in the adoption of better methods; in this test, the combination in proper proportions of preliminary cursory with thorough search. We shall return to this question of adaptability later.

Zeal also played a considerable part in this test. As before pointed out, the attitude in Group B (with certain exceptions) was good-natured acquiescence in the instructions, while that in Group A was one of intense rivalry and desire to make a good record. In no other test was this so definitely manifested, and for the following reason. It was judged best for the sake of uniformity to require all subjects to say the name of the letter (or figure) as they crossed it out. Now while their whole attention was directed upon the search for a letter, the tone of their voice served as a complete betrayal of their frame of mind. One might note the attitudes of dwindling interest, spurts, annoyance, fatigue, determination, anxiety, etc. Particularly interesting was the attitude induced by prolonged lack of success, the subjects here falling into three classes: those who become hopeless and apathetic, those who take a fresh determination, and those who are uninfluenced. The best subjects (speaking broadly) of both groups belong to the second class, the majority of Group B to the last class, and a large proportion if not a majority of Group A to the first class. Their aim being to make a record or to beat a fellow, they became apathetic when this was felt to be impossible. The good natured interest of the Group B boys, while

mistakes were rather frequent. Group A averaged .5 and .36 mistakes per subject for first and second trials respectively. Group B averaged .61 and .35 mistakes per subject for first and second trials respectively.

[13] It is possible that the difference previously remarked between "Letters" and "Alternating" on the one hand, and "Figures" on the other, may be due to the greater novelty of the two former.

not so great, was also not so easily cast down. Nevertheless, although zeal may sometimes overreach itself, the group possessing it has a distinct advantage.

As a result of our experience, we should suggest one or two improvements in the "Alphabet" tests. "Figures" should be given before "Letters." In "Alternating Letters and Figures" the test should be stopped midway—after "13" has been crossed out. This for several reasons: the time and patience of the experimenter would be saved without serious loss, if not a positive gain, in efficiency; most of the mistakes arise from subjects not knowing the order of the latter part of the alphabet; and for young subjects, the strain on the attention in a test such as this, lasting up to ten minutes or more, is too great.[14] Quite possibly it would be well to adopt the same procedure for the other two parts of the test.

It is believed that our form of "Alphabet" tests is an improvement over the "Alphabet Sorting" test used by Burt. Chance arrangements are avoided and the motor element is reduced to a minimum. Printed sheets also save the experimenter's time. As it stands, the test doubtless measures primarily quickness of observation or perceptual discrimination. Attention, concentration, zeal are large factors, and so it would seem, is adaptability, though this is not so obvious nor so demonstrable. A further element of the greatest importance is introduced in the "Alternating" test—the power of dividing the attention, or perhaps more accurately, of rapidly alternating the attention, between two tasks. In all but one case (out of over 150 tested by the writer) the time taken for the "Alternating" greatly exceeds the sum for the "Letters" and the "Figures" separately. It was found that the loss introduced by carrying on the two tasks at

[14] For those who would like to compare results under such procedure with ours we append the following table:

TABLE V

"Alternating Letters and Figures" to M — 13 only

Time in Seconds

	First Testing				Second				Amalgamation			
	Best	Worst	Aver.	Median	Best	Worst	Aver.	Median	Best	Worst	Aver.	Median
Group A	85.8	346.6	146.39	126.2	81.8	235.0	136.7	130.4	84.6	283.3	141.54	128.0
Group B	116.6	372.2	201.46	188.0	75.0	277.4	168.36	173.4	106.9	294.8	184.91	174.0

once amounted to almost one-third, being about 3% less in Group A. This difference, between the groups, in view of the crudity of the method of computation (viz., subtraction), is hardly significant.

We may sum up as follows: The alphabet tests are practicable, reasonably reliable, and yield fairly high correlations with "imputed intelligence." Group A is superior at every point and in every respect, in most respects very markedly so.

5. "Tapping" test

Tapping has been used as a test by several experimenters but the apparatus (designed by Dr. Schuster) used in this test is partly new. Four Veeder stroke-counters closely resembling an ordinary cyclometer were fastened securely to a block of wood clamped to a table. The tapper was of wood about the size of a fountain pen barrel, provided with a substantial rubber tip to prevent slipping from the stroke-counter, and with a bulb-like enlargement near the lower end to provide a secure grip.

The subject was seated a little to the right so that his arm would not be impeded at any time by his body. After showing the subject how to hold the tapper like a pen but rather more vertically, a practice spell of ten seconds was given. All the subjects used a full forearm movement, nearly all of them naturally; the others were asked to use this method in order to keep the conditions uniform. While the subjects rested, after the practice, the instructions were completed. He was to tap as fast as ever he could on each register until told to change to the next, which he was to do without stopping. Emphasis was laid on top speed from the very beginning and the necessity of keeping it up right to the end. Fifteen seconds were given on each register, and the number tapped on each register was separately recorded. A post of the same height as the counters, and at the same distance from the first as the distance between counters, was provided from which to start in order to equalize time conditions on the first counter with those on the others.

The tapping was given in four periods in the hope of obtaining a figure measuring the subjects' "persistence." The effort was very great and not a little painful. In spite of this, however,

most subjects were much interested in the test; and physical fatigue, sheer inability to proceed, can hardly have played any predominating part in so short a series. One must confess to great disappointment with the results obtained. Almost every possible way of treating the figures was used in order to get significant measurements. The falling off from first to last may be a significant figure in itself but it is not a fair measurement of the subject's ability to resist the tendency to slow up. For clearly, almost everything here depends on the initial rate; one subject starts with a great rush which it would be unjust to expect him to continue, another disregards the instructions and starts at a more leisurely rate. If we could assume that each subject started at his maximum rate, then and then only would the falling-off be a true measure of persistency. But such an assumption is unjustified. Regretfully, therefore, we must give up our hope of measuring this most valuable quality. Persistency or rather the ability to maintain the pace, on the one hand, and initial rate, on the other, tend to be negative functions of each other, and in this test they cannot be separately measured.

There remains the total number of taps made in one minute as a measure of the speed of movement plus persistency—a sort of total efficiency. The reliability is very high (.83 $\pm$ .04 for Group B and .66 $\pm$ .07 for Group A). On the other hand, the correlations with other tests are either negative or practically negligible (see Table XVI). In Group B only two are large enough to be accounted of any significance—a small positive correlation with "Dotting" and a slightly larger negative correlation with "Narrative Memory." In Group A, we have a run of negative correlations, some of them considerable. Again, "Dotting" alone correlates with "Tapping," this time fairly well. This tendency for these two tests towards concomitant variation is interesting in view of the fact that both show either negative or no measureable correlation with intelligence. In Group B, tapping shows an index of correlation with "Imputed Intelligence" of only .026—very little more than the P. E.; in Group A, the correlation is — .388 $\pm$ .096.

These correlations are noteworthy in view of the fact that

this is the one test in which the Group B boys, from the laboring class, are unequivocally superior to those of the other group. The following tables and the accompanying diagrams (Fig. V) show the extent of this superiority.

TABLE VI

"Tapping." Total No. tapped in one minute

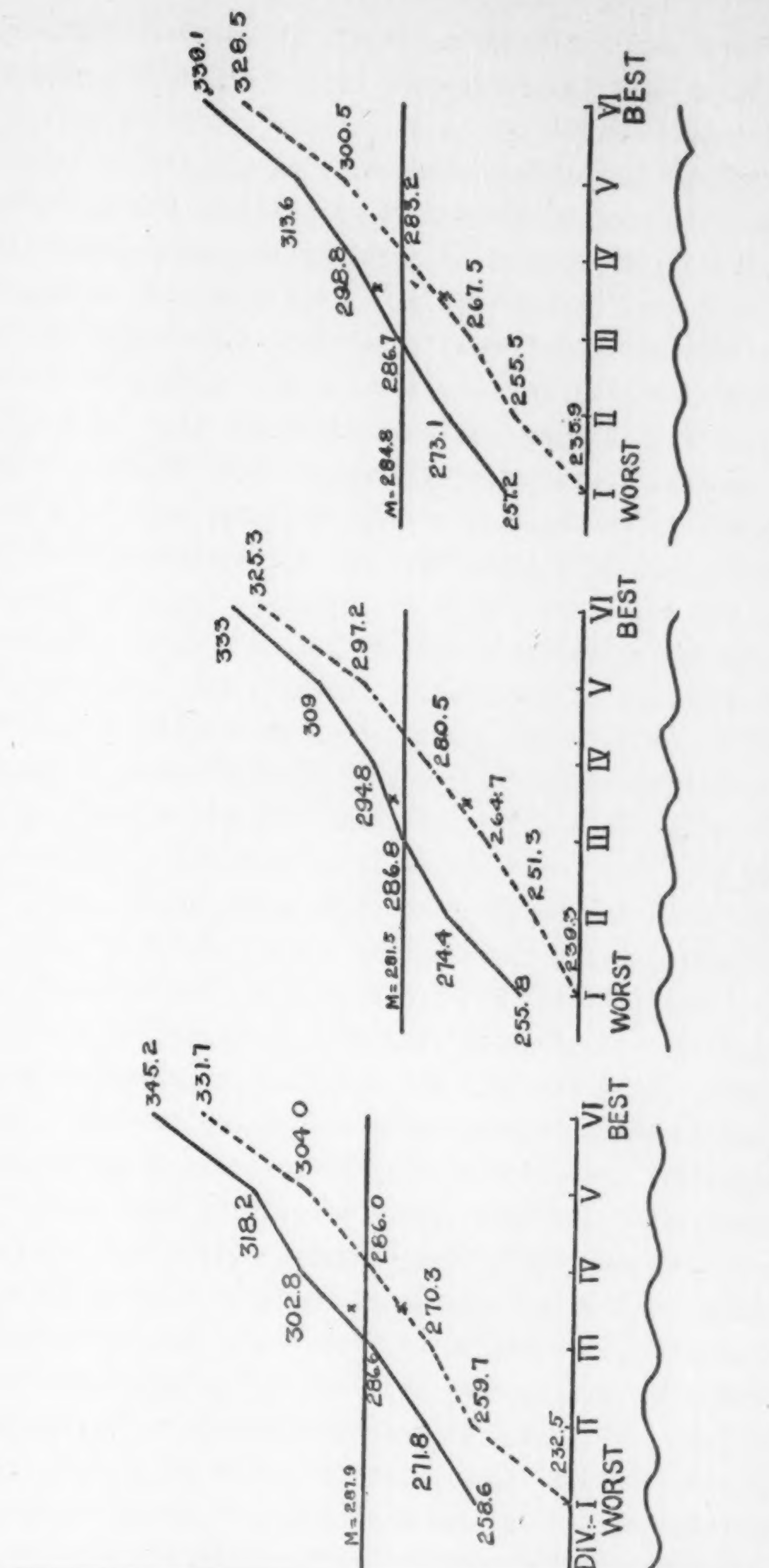
First Testing

	Averages by Divisions I	II	III	IV	V	VI	Best	Worst	Median	Mean	s	E of M
Group A	232.5	259.7	270.3	286.	304.	331.7	346.	202.	278.	280.	34.8	±3.8
Group B	258.6	271.8	286.6	302.8	318.2	345.2	364.	251.	292.	297.	31.7	±3.8
Second Testing												
Group A	239.3	251.3	264.7	280.5	297.2	325.3	343.	158.	270.	273.	31.7	±3.5
Group B	255.8	274.4	286.8	294.8	309.	333.	348.	245.	290.	292.	26.6	±3.2
Amalgamation												
Group A	235.9	255.5	267.5	283.2	300.5	328.5	345.	180.	274.	276.5	33.2	±3.10
Group B	257.2	273.1	286.7	298.8	313.6	339.1	356.	255.	291.	294.5	29.2	±3.5

The superiority of Group B is rather surprising. Although they are a healthy and wholesome lot of lads, they are not so lively and full of spirits as those of the other group. Both schools give regular exercise as well as competitive games but these are more extended at the Group A school. In spite of this we have a very marked and clear cut superiority in a test whose coefficient of reliability is high.

6. "Analogies" test

On the whole this is probably the most satisfactory test used in this investigation. The test was suggested to the writer by Mr. Cyril Burt, who also supplied many of the analogies used. It has since been described by Wyatt (10) and Yerkes (11). In this test the subject was given three words and required to supply a fourth word. Between the first two words certain logical relations obtained; the required fourth word must bear the same logical relation as the third. Obviously here we have reasoning of a fairly high degree, both analytic and constructive. The relations were, however, generally very easy to comprehend and the subject matter was familiar. The test was given as a group test but every possible effort was made to see that each subject understood what he was to try to do before beginning.



345.2
331.7
318.2
304.0
302.8
286.0
270.3
259.7
M=281.9
271.8
232.5
258.6
DIV.:- I WORST
II
III
IV
V
VI BEST
333
325.3
309
297.2
294.8
280.5
264.7
286.8
251.3
M=281.5
274.4
255.8
I WORST
VI BEST
338.1
328.5
313.6
300.5
298.8
285.2
267.5
286.7
255.5
M=284.8
273.1
235.9
257.2
I WORST
VI BEST

FIG. V.

The following was the explanation which was, however, supplemented by questions and answers both on the part of experimenter and subjects.

"Most of you have done proportion in arithmetic, I suppose. We are going to have a new sort of proportion. Instead of numbers we shall have words. For example, as a father is to his son so is a mother to her—what? [All examples were written on the blackboard so as to familiarize the subjects with the form. The correct answers were also written in.] 'Daughter.' Right. As a tree is to a sapling, so is a man to a—'boy.' Let us take another. Book : page :: congregation : ——. Hands. 'People?' No, a person. You see it was only one page so it will be only one person. Now let's see what we have been doing. We notice first that the first two words go naturally together; they are relations or are somehow connected, aren't they? In the first one it was a case of parent and child, in the next of old and young, then of whole and parts. Now in the list of words you are to work with, the first two will always be connected something like this. The things the words name will always have something to do with each other, just as the things above named did. Then there will be the third word and a blank space. What you are to do is to fill in the blank space. Now just any word won't do. It must be a word that is like or different from the third word, connected with the third, just exactly the same as the second is like, different from or connected with the first. Let us take one or two more examples. Suppose you had: North : South :: East : ——— 'West.' That's right. That's easy, isn't it? Now notice this one pretty carefully. North : Pole :: Left : ———. 'Right?' No. That is wrong. I put this one up to fool you. It is an impossible question. There is no answer. I just wanted you to notice that you can't answer these unless you think. We get so used to 'left-right, left-right' that we answer 'right' without thinking; that won't do. You must *think* on *every one* of these. But notice this. On the papers you have there are no 'foolers.' *There is an answer to every single question.* Only to get the answer you must *think*. Ask yourself how the first and second are connected and try to find a word as like the third as the second is like the first. Now if any one

is not entirely clear what he is to do, I hope he will ask me a question now. This is hard and you want to get it right, so now is the time to ask. When I give you the command 'Turn' all should turn their papers over and begin work. Don't take too long over any one set but go on to the others and come back to it. Finish as many as possible but it is more important to get them right. Ready? Turn!"

Shortly after they had begun, the experimenter announced that he was ready to explain the meaning of any words. At five minutes they were warned to be at least half through. Eight minutes were allowed with slight extensions for the younger boys, who wrote slowly. The writer acted as experimenter throughout this test. The instructions for the second trial were as follows:

"We are going to have another set of those papers in which you fill in the missing fourth word. And I want to call your attention to some common mistakes. No. 3 on the old paper is a good example. 'Weak : Strong :: Sickness : ———.' Many of wrote 'Healthy.' That won't do. Healthiness or health is what is related to sickness as weak is to strong. Or if we had had 'Ill' then 'Healthy' would have been right. Good : Better :: Bad : ———. Would you believe me when I say many of you wrote 'Worst'? Of course it is 'Worse.' Bricks : Walls :: Tiles : ——— 'Roofs.' So many had just 'Roof.' But 'Walls' means more than one wall and 'Roofs' must correspond.

"Now let's have one more illustration of the way to go about the test. Suppose we have England : London. What is the relation? No, that is too easy. Say Sheffield : Steel. What is here the relation? the connection? City to its chief product. Then if we put down Nottingham here in the third place, all we have to do is to put in Nottingham's chief product which is lace. You must *first* make out the connection of the first pair and the rest is generally easy. Has any one a question? Well, you may not have as long a time as before, so look sharp. Ready? Turn!"

Boys whose first trial had been conspicuously bad were questioned until they seemed to get the idea. It is not an easy matter to explain this test so that the children will understand the nature

of the task. Those materially younger than the boys who did these tests for us conspicuously fail.

One was scored against each subject for each mistake. Mistakes merely in the grammatical number of the reply counted only ¼. The following two lists of analogies were used for the two trials.

First List

1. Eating : Hungry :: Drinking : ————
2. Stationer's : Notepaper :: Butcher's : ————
3. Weak : Strong :: Sickness : ————
4. Black-Lead : Pencil :: Ink : ————
5. Good : Better :: Bad : ————
6. Shirts : Flannel :: Boots : ————
7. Head : Headache :: Tooth : ————
8. Master : Servant :: Teacher : ————
9. Bricks : Walls :: Tiles : ————
10. Preaching : Clergyman :: Healing : ————
11. Birds : Flying :: Fishes : ————
12. 5 : 10 :: 10 : ————
13. Seeds : Plants :: Eggs : ————
14. Needle : Prick :: Knife : ————
15. Laundress : Linen :: Bootblack : ————
16. Dinner : Mid-day :: Supper : ————
17. End : Death :: Beginning : ————
18. Forget-me-not : Blue :: Poppy : ————
19. Clothes : Tailor :: Boots : ————
20. Hills : Mountains :: Lakes : ————
21. Necklace : Neck :: Bracelets : ————
22. Eating : Table :: Writing : ————
23. Drinking : Cup :: Eating : ————
24. Horses : Carts :: Engines : ————

Second List

25. Sofas : Cushions :: Beds : ————
26. House : Door :: Body : ————
27. Miaow : Cat :: Bow-wow : ————
28. Ocean : Ship :: Air : ————
29. Hair : Man :: Fur: ————
30. Doctor : Illness : : Dentist : ————
31. Mother : Child :: Cat : ————
32. Wires : Telegrams :: Postmen : ————
33. Sponge : Slate :: India Rubber : ————
34. Half : Whole :: Semi-Circle : ————
35. North : South-West :: South : ————
36. Cricket : Bat :: Tennis : ————
37. Fold : Sheep :: Stables : ————
38. Coals : Mines :: Wood : ————
39. Getting Up : Sunrise :: Going to Bed : ————
40. A Carpenter : Wood :: A Smith : ————
41. Buttercups : Daisies :: Yellow : ————
42. Grass : Hay :: Wheat : ————
43. Drunkards : Drinking :: Gamblers : ————
44. Please : Thank You :: Asking : ————
45. Thread : String :: String : ————
46. Geography : Astronomy :: Earth : ————
47. University : School :: Students : ————
48. Twelve : One :: A Shilling : ————
49. Time : Clock :: Lengths : ————
50. Trout : Fish :: Sparrow : ————

The reliability of the test is unusually high. (Coefficients: Group B, .78 ± .05, Group A, .65 ± .071.) The various correlations may be seen by reference to Table XVI. The especially high correlations with "Imputed Intelligence" in both groups should be noted. In our judgment this is not relatively high enough. No single test is a fair measure of intelligence but we feel that this test comes nearer such than any other we are familiar with. Its chief defect is a certain unfairness to the better subjects who never take anything like the full time for the test.

The superiority of Group A is not quite so striking as in one or two other tests but is decided and unequivocal. One should notice the way in which the two curves approach each other at the better end. An unusual feature of the test is that the best subject of all was a member of Group B. Table VII gives all the more significant figures. The curves appear in Fig. VI.

TABLE VII

"Analogies." Results in No. of errors

	Averages by Divisions I	II	III	IV	V	VI	Best	Worst	Median	Mean	s	E or M
First Testing												
Group A	11.04	2.83	1.25	1.	.42	.04	0	22.	1	2.82	4.17	±.462
Group B	18.4	9.	5.4	4.3	2.5	1.0	0	22.5	4.5	6.7	6.32	±.757
Second Testing												
Group A	9.79	6.5	4.25	2.75	1.71	1.0	1	12.5	3.	4.24	3.0	±.333
Group B	19.1	10.55	8.25	6.55	4.05	2.0	0	24.5	7	8.36	6.04	±.725
Amalgamation												
Group A	10.83	4.67	2.75	1.88	1.06	.52	.5	16.56	2.5	3.53	3.82	±.425
Group B	18.75	9.78	6.82	5.42	3.28	1.5	0	22.	6.25	7.53	6.17	±.74

It is clear from our experience that the test may be decidedly improved. The list of analogies as here given is far from perfect. To avoid ambiguity, purely verbal associatons, etc. we suggest the following substitution:

For no. 2 Note paper : Stationer's : : Meat : ———
" " 5 Better : Good : : Worse : ———
" " 20 Lakes : Seas : : Hills : ———
" " 22 Writing : Desk : : Eating : ———
" " 23 Cup : Drinking : : Plate : ———
" " 25 Cushions : Sofas : : Pillows : ———
" " 26 Body : Mouth : : House : ———
" " 36 Racquet : Tennis : : Bat : ———(Baseball or Cricket.)
" " 37 Sheep : Fold : : Cattle : ———
" " 41 Buttercups : Easter Lillies : : Yellow : ———
" " 49 Lengths : Ruler : : Time : ———

Nos. 12, 16, 39, and 46 should be entirely omitted. Nos. 22 and 23 should be separated. It will be noticed that most of these changes make the test easier; this is not, however, the aim but merely to insure fairness. Certain of the remaining questions are still difficult enough to make even adults think twice.

A more radical change in procedure would be to give the test to the subjects individually rather than in groups and to limit the time allowed for each reply—certainly not more than 10, and probably not more than 7 or 8 seconds. For such procedure the "analogies" could be printed on separate cards. The advantage of the change would be to give a fairer comparison—since the

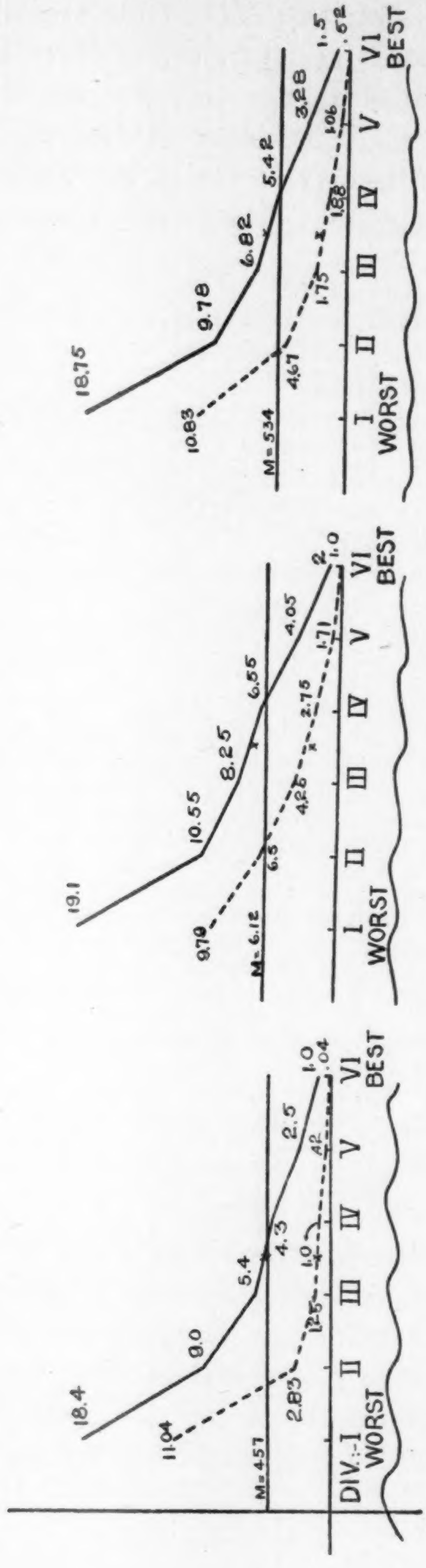

18.4
9.0
5.4
4.3
2.5
1.0
11.04
2.83
1.25
1.0
.42
.04
M=4.57
DIV.:-I
WORST
II
III
IV
V
VI
BEST
19.1
10.55
8.25
6.55
4.05
2
9.79
6.5
4.25
2.75
1.71
1.0
M=6.12
I
WORST
II
III
IV
V
VI
BEST
18.75
9.78
6.82
5.42
3.28
1.5
10.83
4.67
1.75
1.88
1.06
.52
M=5.34
I
WORST
II
III
IV
V
VI
BEST

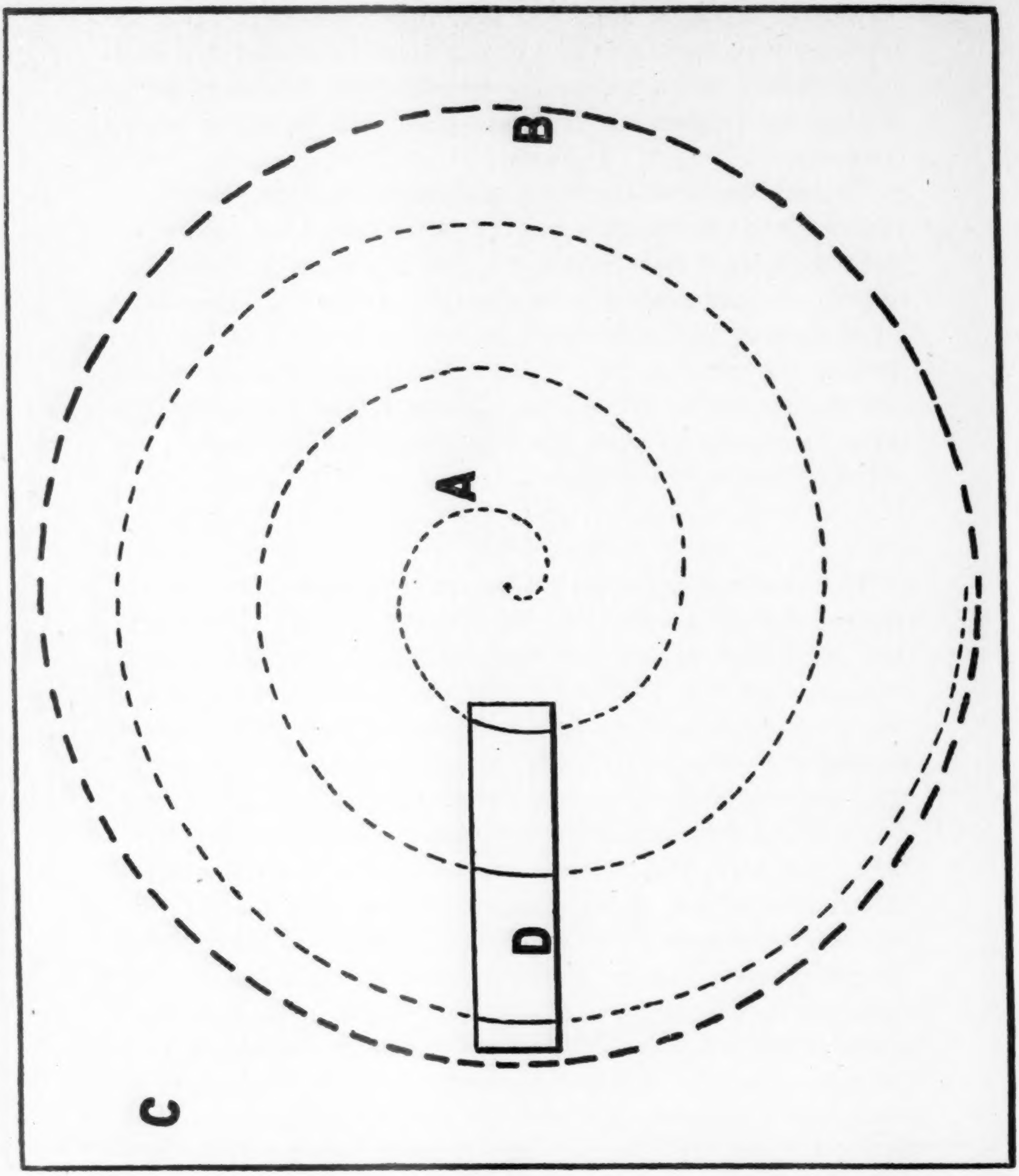
Fig. VI.

better subjects take much less time than the poorer. Our experience with the "Discs and Circles" test described below leads us to believe that a counter for recording the number of errors during the progress of the test would then be found almost necessary.

The explanatory instructions need careful revision. Ours were the result of our experience at the parish school but further experience proved them insufficient. It is immensely difficult to explain this test to children because of one's tendency to describe in abstract terms. Even those children, it is to be feared, who grasped the nature of the task from the examples, failed to understand parts of the instructions. It would be better to illustrate (almost entirely by numerous examples, carefully selected) the different cautions to be enforced.

7. "Dotting" test

This test was suggested by Professor McDougall. The apparatus was improved first by Dr. Rivers and then by Dr. Schuster. The form used by us may be called the Disc-Dotting machine (see Fig. VII). An irregular row of small circles 2 mm. in diameter is printed spirally in red on a paper disc 326 mm. in diameter. The spiral makes altogether two complete turns. The circles (which have their centers indicated by a red dot) are carefully arranged so that their succession shall be as irregular as possible. The interval between successive circles, in the direction of motion of the spiral, was 5 mm.; the lateral deviation was never more than 7 mm. The circles were thus clustered irregularly about the "true" line of the spiral (the latter represented by A in the figure). The paper disc is mounted on a horizontally disposed plate (B) made to rotate by clock-work at a constant rate. In our case a gramophone motor—very silent in movement—was used. A cover (C) is supported above the plate in which a slot (D) one inch wide is cut in such a position and of such a length that, as the disc rotates, every point in the spiral row of circles presents itself to view through the slot. The subject rests his wrist on the cover and aims at the circles as they appear through the slot at one edge and are carried out of sight at the other. He starts at the inner end of the spiral and makes



his way outwards over it as its whole length presents itself point by point through the slot. This compels him to aim at the circles at a gradually increasing rate. At the inner end of the spiral

an angular movement of 45° brings seven circles out from under the edge of the slot; at the outer end of the spiral 24 circles are shown by the same angular movement. Thus the subject has to aim more than three times as fast as at the inner end. The clock-work was set to make a complete rotation in 40.5 seconds. Thus at the beginning the subject has to aim 83 times per minute, at the end of the spiral, 286 times. The former is well within the powers of any normal subject over ten or eleven years of age, the latter is too difficult for all children and for practically all adults. Hence it must happen that somewhere between the beginning and the end a point is found for each subject at which the rate of aiming becomes too rapid for him. This point is the measure of the dotting ability of the subject.

The instructions for this test were brief and of less importance than for most tests. The subject here learned preeminently by doing and by seeing. Each saw the test performed by one of his fellows, and thus grasped the general idea (which was nevertheless enforced by precept) that the circles come faster and faster as one works one's way out. The boys were told to aim at the circles as soon after they came into sight as possible—i. e., to keep the work at the "upper" edge of the slot or "window." They were not to try to correct errors ("which only count as two errors instead of one and get you behind"), not to stop until given permission, and not to give it up as they might be doing better than they thought. A comfortable and convenient posture, grasp of the pen, etc., was prescribed. The subject was seated fairly high above the machine, the light in front and a little to the left. If a subject became "rattled" and was obviously losing out, he was told to skip a few and take a fresh start. If he was able to maintain himself, no account was taken of the temporary lapse. In order to give subjects the same amount of practice, they were all forced to finish the entire spiral the first time but on the second testing were stopped when their limit had obviously been reached.

The subjects were graded according to the breakdown-point. This was estimated as follows: A "miss" was a circle not hit and any mark on the paper not obviously directed at some circle.

All extra marks were thus "misses" but marks aimed at a circle and not hitting it counted only as one miss, not one for the circle and one for the mark. Beginning with the first "miss," ten circles forward were counted. A breakdown consisted of five misses out of ten. If, however, the subject could then recover and for two successive series of ten circles keep up with the machine, the breakdown was not counted. The eventual breakdown was scored from the beginning of that series of ten in which it occurred. The entire spiral was divided into 23 sectors by radial lines. After the breakdown, the subject was given a grade according to the nearest fourth of these sectors. The range was from 6½ to 20½. It will be noticed, however, that a difference of one-fourth of a sector amounts to a great deal more at 17 to 17¼ than at the less peripheral 8½ to 8¾. This does not affect the arrangement into ranks for the better subjects are more sharply differentiated anyway, but it does affect the comparison of the two groups. The number of circles was therefore counted for each quarter-sector and the score given was according to the number of circles aimed at by the subject before his breakdown. (Not, it is to be remarked, the actual number hit, the sporadic misses up to the breakdown-point being of no importance.) The range is thus from 57 to 292 circles aimed at.

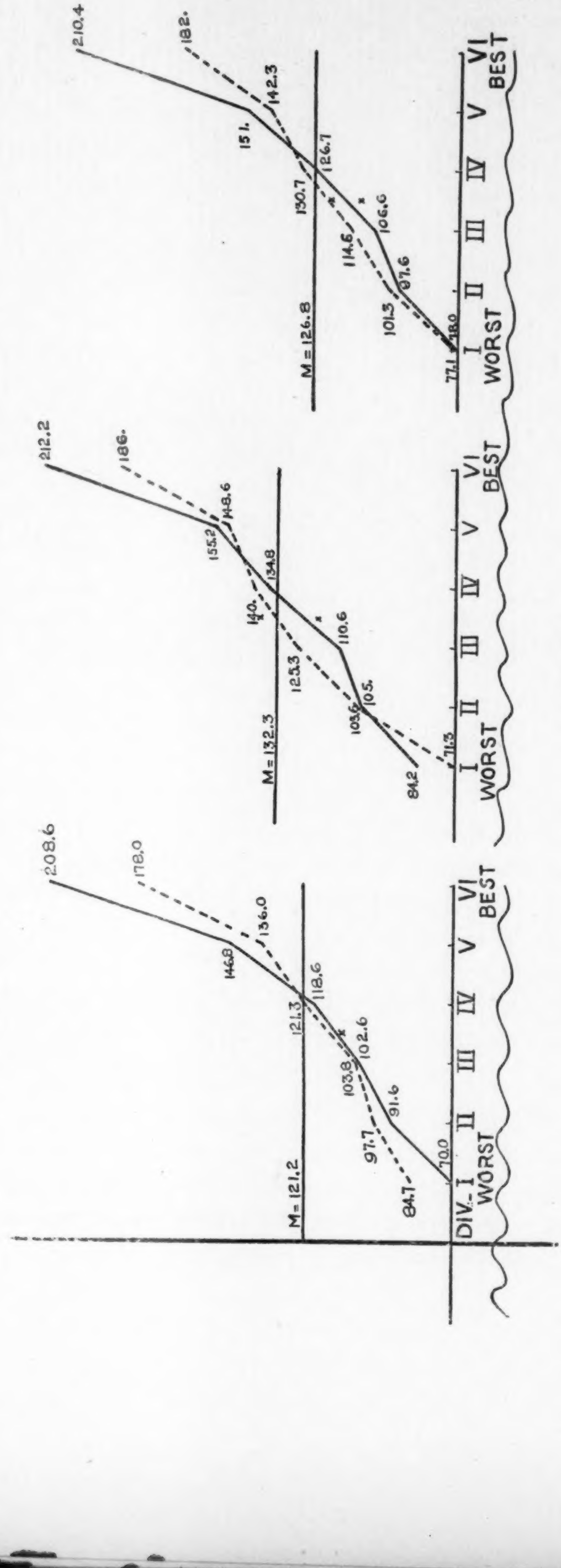
The reliability of the test is very high. In spite of its being given at rather widely different intervals and by different experimenters, the coefficient of reliability is $.729 \pm .061$ in Group B and $.723 \pm .054$ in Group A.

The table of correlations records some very interesting and baffling results. In Group A, "Dotting" shows a high positive correlation with "Tapping." Its correlations with other tests are identical or closely similar to the correlations between those same tests and "Tapping." This seems clearly to point to the conclusion that the same element largely determines excellence in these two tests—most probably the speed of movement factor. By the method of multiple correlation, however, we find that "Dotting" has a negative correlation of $-.20 \pm .11$ with "Immediate Memory," even when "Tapping" is constant. There is zero correlation with "Analogies," "Narrative Memory" and

"Imputed Intelligence" and positive correlation of .24 ± .11 with "Spot Pattern" and "Related Memory." We have here, then, some function not present in "Tapping" and one which seems to correlate more highly with the more "intellectual" tests.

When we turn to Group B, we find some curious changes. All of the correlations are positive, several being considerable. The correlation with "Tapping" is no longer marked. If by the method of multiple correlation, we render the element common to "Tapping" and "Dotting" constant, we scarcely affect the amount of the correlations of "Dotting" with other tests. In Group B, then, the speed of movement factor, which operated in "Tapping," does not seem to be of primary importance in the correlations of "Dotting." The determining factor is some function of but moderate yet appreciable correlation with intelligence.

That a test may exercise one function in one group, another function in another, is clear enough when the two groups are quite different in respect to training or native ability. Taking the lower half of Group A, based on "Imputed Intelligence," it was found that "Dotting" correlated with "Imputed Intelligence" with an index of .19 ± .16. It would seem, therefore, that as general intelligence decreases, "Dotting" becomes more and more correlated with it, i. e. its diagnostic value is greater for the less intelligent. The diagrams (Fig. VIII) give some hint of this, for this is the only test in which the lines in the diagrams cross. That is, on the first testing, the poorer subjects of Group A are better than the poorer subjects in the other group. As we approach the mean, they are more and more equal until the relative positions are changed and we find the two best divisions of Group B quite noticeably better than those of Group A. The mean for the latter group is slightly larger and a smaller percentage fall below the amalgamated mean for the two groups. This slight superiority is increased upon the second testing. Table VIII gives the more important figures.



208.6
178.0
146.8
136.0
121.3
118.6
103.8
102.6
97.7
91.6
84.7
70.0
M = 121.2
DIV. I II III IV V VI
WORST
BEST
212.2
186.
155.2
148.6
140.
134.8
125.3
110.6
103.6
105.
84.2
71.3
M = 132.3
I II III IV V VI
WORST
BEST
210.4
182.
151.
142.3
130.7
126.7
114.6
106.6
101.3
87.6
77.1
78.0
M = 126.8
I II III IV V VI
WORST
BEST

Fig. VIII.

TABLE VIII

"Dotting"—Results in No. of circles before breakdown

	Averages by Divisions											
	I	II	III	IV	V	VI	Best	Worst	Median	Mean	s	E of M
	First Testing											
Group A	84.7	97.7	103.8	121.3	136.0	178.0	207	63	108	120	12.50	±1.39
Group B	70.0	91.6	102.6	118.6	146.8	208.6	292	57	108	122.5	20.14	±2.44
	Second Testing											
Group A	71.3	105.0	125.3	140.0	148.6	186.0	221	66	138	131.7	14.6	±1.62
Group B	84.2	103.6	110.6	134.8	155.2	212.2	247	57	119	133	18.72	±2.26
	Amalgamation											
Group A	78.0	101.3	114.6	130.7	142.3	182.0	205	69	121.5	125.8	13.4	±1.49
Group B	77.1	97.6	106.6	126.7	151.0	210.4	244	57	115	127.8	19.32	±2.34

It is obvious from the above that the two groups are practically even in their achievements in this test. The diagnostic value of the test for children of ordinary intelligence is, to say the least, doubtful. Certain of the very dull subjects in both groups were very bad at this test but with them were bracketed several of the brightest.

The test was used in the hope of measuring voluntary attention. One of the workers in the Oxford Psycho-Physical Laboratory has tested herself daily for long periods, using the McDougall-Rivers Dotting Machine, and has found it a most delicate and responsive test of attention. The writer is convinced, however, that for children it is not so effective and he questions its availability for general use as a diagnostic *test* even for adults. The subject above referred to had, by long practice, reached her maximal performance. Any lapses of attention resulted in a decrease from the normal. During the process of establishing such a normal performance, however (and it was of course in such a formative period that our records were taken), other than attention factors, chiefly perhaps manual dexterity and coolness, play a greater part in the determination of rank.

8. "Spot Pattern" test

The "Spot-Pattern" test was first described by Burt (2) and was devised by Professor McDougall. The portable tachisto-

scope also devised by him is described by Burt in the following terms: "It consists of a vertical stand of wood attached to a horizontal base by a hinge—which allows it to fold forward when not in use—and by a detachable spring, which keeps it upright when hooked to it at the back. In the upright stand is cut a circular aperture about 7 cm. in diameter; and at the back of this is screwed a Packard-Ideal Shutter with an aperture of 2¾ inches in diameter; while the front—for ordinary tachistoscope experiments—is covered with a semi-transparent card, sliding in grooves fixed on the face of the stand, and bearing printed in its hinder surface the object to be shown by means of the tachistoscope. The card is illuminated for a fraction of a second by transmitted light from a lamp placed behind the stand, the duration of the exposure being regulated by the shutter."

In the "Spot-Pattern" test the cards were of different nature. An irregular but carefully prepared pattern was made by piercing from four to eight large pin-holes in opaque squares of cardboard. Over the surface to be presented to the boys was pasted a square (1½ x 1½ inches) of moderately thick paper ruled into 36 smaller squares.

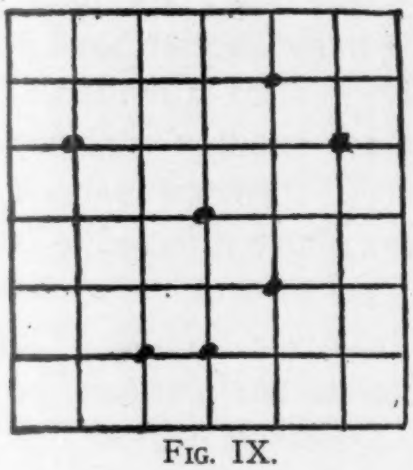


FIG. IX.

When the tachistoscope was open the pattern made by the light shining through the holes in the card and through the paper fell entirely within the larger square, each spot of light falling directly on one of the 25 inside corners. The subject was provided with sectional paper which duplicated precisely that used to cover the pattern. A sample card with nine spots was inserted and the shutter held open as for a time exposure. To avoid after-images,

the room was kept dusky rather than dark. The following instructions were given:

"Do you see those spots? Well, notice how they are arranged. Each one falls on a corner. And the card is ruled like this page, isn't it? With another card something like this, I am going to show you some light spots and I want you to copy the pattern from memory. You'll not get to look at them long, but in 3 short flashes like this. [Illustrate, counting the flashes aloud.] After the third flash I want you to put a cross on the corners here [on the sectional paper] corresponding to the corners here [on the card]. That is, if there should be a spot of light here, you should put a cross here [pointing in both cases]. If there, then there. You must get them on the exact corner as nearly as you can. Now do you understand? You wait till after the third flash and then copy down the whole pattern as soon as you can, so as not to forget it. This first card has only 4 spots. Start with your eyes looking at the center here. Ready? One—two—three" (opening the shutter just after each count). The exposure was about 1-10 of a second, the interval between exposures was as near 2 seconds as possible. Mistakes on the first card were pointed out and the subject urged to greater effort and attentiveness. "There will be four spots again this time. You ought to get them *all* right." There were two cards for each number of spots—from four to eight inclusive. Generally it was found wise to explain also the mechanism of the tachistoscope to the boys as several were burning with curiosity to know how the flashes were produced.

Important changes in procedure from that adopted by Burt (2) will be noticed. These were introduced primarily to save time, as he found the test very long and tedious, the number of required flashes sometimes being as high as 150. In the present form, 30 flashes are given for each subject. This is sufficiently tedious. About a month intervened between the first and second testings. One point was scored for each spot correctly located.

The reliability of this test is exactly the same in the two schools, $r = .412$. The correlations with other tests present only two noteworthy features (Table XVI). There is a markedly

lower correlation between all parts of the "Alphabet" test and the "Spot Pattern" in Group B than in Group A. Except for the correlation of "Spot Pattern" with "Alternating," however, this is more apparent than real, since the differences lie within the margin of their probable errors. It is somewhat difficult to conjecture what should be the ground of a rather high correlation in one group, this correlation being almost lacking in the other. Exactly the same point is raised in connection with the three memory tests. No manner of juggling can make a correlation of .064 ("Spot Pattern" with "Immediate Memory," Group B) a possible equal of one of .496 ± .088 (Group A).[15] In Group B the correlation with "Imputed Intelligence" is very low, almost negligible; in Group A the correlation is rather high. One is very sorry at this point that the method of provisionally estimating intelligence in the latter case is so crude. As it is, all that one dares conclude is that the test shows a small but positive correlation with intelligence.

TABLE IX

"Spot Pattern"—Results in No. of Spots Located

	Averages by Divisions I	II	III	IV	V	VI	Best	Worst	Median	Mean	s	E of M
Group A	19.17	22.67	26.	29.	31.17	36.	43	17	20	27.32	5.37	±.596
Group B	18.	20.4	23.	24.4	27.	34.	37	15	24	24.23	5.62	±.68
Second Testing												
Group A	19.7	24.	26.	28.7	31.5	35.	37	14	27	27.46	5.33	±.59
Group B	17.4	21.2	23.4	26.6	29.8	32.6	36	15	25	25.13	5.62	±.68
Amalgamation												
Group A	19.37	23.33	26.	28.85	31.33	35.5	40	20.25	27.75	27.39	5.76	±.64
Group B	17.7	20.8	23.2	25.5	28.4	33.3	35.5	18.5	24.5	24.68	5.56	±.67

As will be clearly seen from Table IX and Fig. X, the difference between the two groups is not great, although the superiority of Group A is well beyond the accidental. With another system of marking this would be slightly greater, for it is obvious

[15] It is interesting to note that Burt got the same anomalous result. In Group B the correlation of "Memory" with "Spot Pattern" was .26 ± .11, in Group A .74 ± .09. While Burt's technique was different, it seems likely that the same function was tested. He gets fairly high correlations with estimated intelligence at both schools.

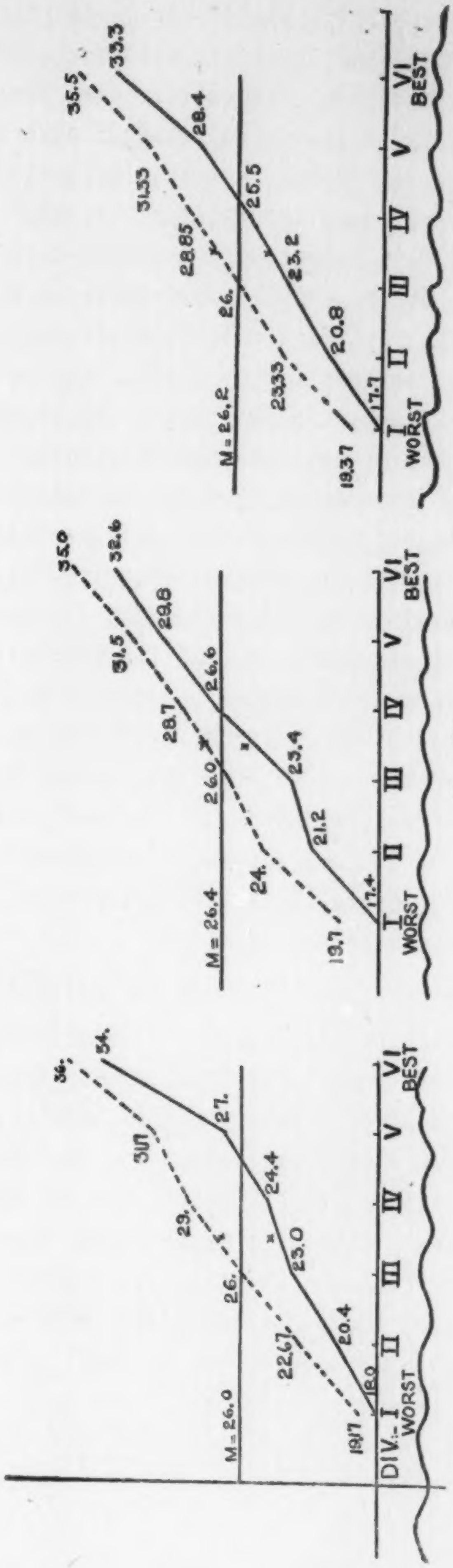

M=26.2
19.37
23.33
26.
28.85
31.33
35.5
33.3
28.4
25.5
23.2
20.8
17.7
I WORST
II
III
IV
V
VI BEST
M=26.4
19.7
24.
26.0
28.7
31.5
35.0
32.6
29.8
26.6
23.4
21.2
17.4
I WORST
II
III
IV
V
VI BEST
M=26.0
19.17
22.67
26.
23.
30.17
34.
34.
27.
24.4
23.0
20.4
18.0
DIV.: I WORST
II
III
IV
V
VI BEST

Fig. X.

that the scoring was rather crude. A subject might learn the pattern quite correctly but locate it a square to one side, thus perhaps getting none right. Another subject simply puts down the requisite number of points at random and his chances of getting some one or two right are good. It seemed unwise, none the less, to introduce a more complicated scoring. It is exceedingly laborious. One's judgment is involved and this is notoriously not a static thing. And finally there is the doubtful or rather low correlation of the list with intelligence.

The test aims at testing a very useful function or group of functions of intelligence—chiefly range of attention and the ability to apprehend and remember relationships—at least spatial relationships. The question is, does the test measure these functions? And to this one must answer "only partially." The combining of attention with the relation-grasping function is rather unfortunate and on the whole unnecessary. The element of luck is rather large (although the reliability coefficient of .41 would seem to indicate that it was not so large as it had seemed to the writer in giving and in marking the test) and can not be eliminated. It seems to the writer that one would do better to use separate tests for attention (there are several pretty good ones) and for relations of various kinds. The portable tachistoscope is very handy and may well be retained for many of the simpler tachistoscopic experiments or tests.

9. "Related Memory" or "Memory for Related Words" test

It is thought that the test is a new one, although it resembles many other memory tests. No apparatus beyond a stop-watch is required. The subject is instructed as follows: "I am going to read you a list of words and when I've finished I'll give you the first one and you are to repeat the rest of the words in the order I read them to you. All these words have some sort of connection with each other. For instance, suppose I read 'eyes—blue—red.' Eyes are connected with blue because they often *are* blue, and blue with red because they are both *colors*. But this is not to say there's a connection between eyes and red. Each word is connected with the word going before and the word coming after it. And as a little 'tip' let me say that the better you notice

the connections, the better you'll remember the words. So notice these connections while I read slowly. Then I'll tell you the first word and you go right through the list. If you make a mistake, I'll correct you, e. g., if you say 'eyes—red,' I'll say, 'No, eyes?' and wait for you to give blue, i. e., I'll repeat the last correct word you said. If you can't think of a word in time, I'll prompt you—and of course score it against you. Now are you quite sure you understand what you are to do?"

One of the following lists of 21 words was then read at the rate of 1 in about 2½ seconds. The tempo was kept fairly constant by repeating each word silently before reading the next, as well as by watching the stop-watch. List 1 is read for the first testing, list 2 for the second and list 3 is kept in reserve—since it frequently happens that a test is spoiled by interruptions, misunderstanding, etc. It is thought that the 3 lists are of fairly equal difficulty, though much depends upon the accidents of training. It will be noticed that some of the words are equivocally used. This is intentional as it makes the task a little harder and thus gives more scope for intelligence.

List 1	List 2	List 3
bird	top	nut
nest	spin	crack
bush	spider	cracker
garden	fly	Christmas
house	run	holly
roof	cricket	prick
chimney	bat	pin
fire	night	steel
heat	cold	knife
boil	marble	cut
milk	round	cake
cow	ring	current
grass	light	river
green	moon	water
color	man	rat
paint	policeman	white
dry	beat	pale
dust	stick	pink
march	glue	cream
hare	gum	yellow
red	tooth	sands

In recall, the subject is given 10 seconds for each word. If he fails to recall it in that time he is prompted and told to continue. Corrections were made as described in the instructions.

If, when a subject is corrected for the proleptic insertion of a word actually in the list, he recalls the right word within the 10 seconds, the score against him is only 1. Other insertions count 2, as do promptings.

The test was a reliable one, the coefficients of reliability being .446 ± .094 and .508 ± .104 for Groups A and B respectively. The other correlations (see Table XVI) exhibited by this test are very interesting and not a little anomalous. Take first Group B. The low correlation between this test and the "Spot Pattern" is a case in point. Both these tests involve the apprehension of relations, the one of spatial, the other of verbal or conceptual relations. Yet the correlation between the two in this group is just barely more than the probable error. The low correlation with "Imputed Intelligence" is another surprising and disappointing result. Its correlation with the order of the amalgamated tests is on the other hand very high.

Turning now to Group A, we find some curious changes. The correlation with the "Spot Pattern" becomes, as one would expect, moderately high. "Dotting," which gave a fairly high correlation with this test in Group B, here gives no correlation whatever. Except "Immediate Memory," "Tapping," "Dotting," and "Age," all the tests show in this group higher correlations with "Related Memory." Thus the few indications we have, including the fairly high correlation with "Imputed Intelligence," indicate that this test does correlate with intelligence in this group. One is somewhat at a loss to account for the divergencies between the two groups.[16]

[16] Miss Bickersteth and I did not practice this test together as much as the others and accordingly showed more individuality in applying it. Group A was first tested, followed closely by Group B. It so happens that while she tested the majority of the latter group, I tested the majority of the former.

TABLE X

Group B

1st Time Over,	2d Time Over,	Changes in Rank
Tested by M. B. 18	18	14 gain 4 lose
Tested by H. B. E. 13	M. B. 10	1 gains 1 no change 8 lose
	H. B. E. 3	3 lose

TABLE XI

"Related Memory"—Results in No. of errors

First Testing

	Average by Divisions I	II	III	IV	V	VI	Best	Worst	Median	Mean	s	E of M
Group A	18.33	8.5	6.	4.	2.75	1.25	0	24	5	6.76	6.11	±.677
Group B	26.8	22.2	18.8	14.8	12.6	9.	4	30	17	17.35	6.53	±.791
Second Testing												
Group A	20.83	15.83	13.83	6.5	5.5	1.83	0	31	10	10.68	7.22	± .8
Group B	34	27.6	23.	18.2	15.2	11.	6	38	20	21.45	8.44	±1.022
Amalgamation												
Group A	19.56	12.16	9.92	5.25	4.13	1.54	0	22	6	8.72	6.53	± .724
Group B	30.4	24.9	19.4	16.5	13.4	10.	11	32	20.83	19.4	7.54	± .913

In no other test except "Narrative Memory" is the superiority of Group A so pronounced as in "Related Memory" (Fig. XI and Table XI). The worst (1st) division is seen to be as good at this test as the 3d division of Group B and the best division of Group B is not so good as the 3d best division of the rival group. That this is not due to the different experimenters is seen from the fact that it is greater in the first testing where Miss Bickersteth and I more evenly divided the groups than in the second testing.

TABLE X (continued)

Group A

1st Time Over,	2d Time Over,	Changes in Rank
M. B. 6	H. B. E. 3	2 gain 1 loses
	M. B. 3	2 gain 1 loses
H. B. E. 31	M. B. 9	3 gain 6 lose
	H. B. E. 22	2 no change 12 gain 2 lose

The interpretation of the above information is, however, far from easy. It might seem that the subjects found my peculiarities of method slightly the easier. If the test really correlates with intelligence in Group A (where I did most of the work) and if this greater ease is the cause, the section tested by me in Group B should exhibit higher correlation with intelligence than that tested by Miss Bickersteth. This is not the case. One safe inference we may draw—that personality and slight changes in method have an influence seemingly beyond all expectation—a point constantly to be borne in mind in working with tests.

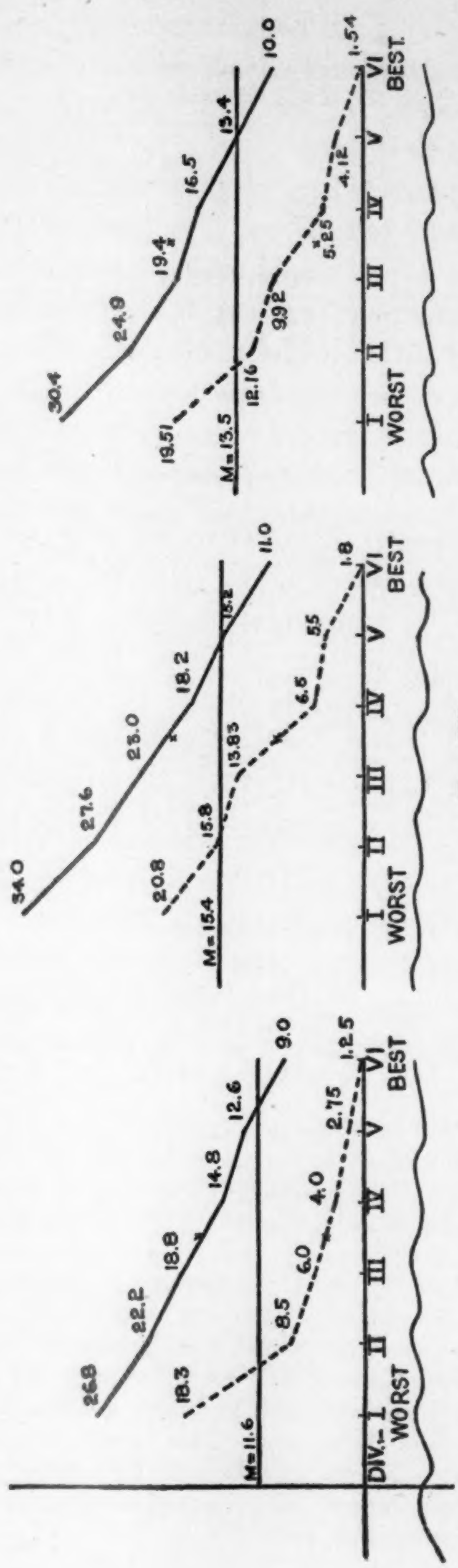

26.8
22.2
18.8
14.8
12.6
9.0
18.3
8.5
6.0
4.0
2.75
1.25
M=11.6
DIV.— I
II
III
IV
V
VI
WORST
BEST
34.0
27.6
23.0
18.2
15.2
11.0
20.8
15.8
13.83
6.6
5.5
1.8
M=15.4
30.4
24.9
19.4
16.5
13.4
10.0
19.51
12.16
9.92
5.25
4.12
1.54
M=13.5

Fig. XI.

The test seems to us a very useful one and requires very little time and no apparatus. If younger or older subjects are to be treated, the number of words can be decreased or increased and the conceptual relations between the words made more or less obvious.

10. "Narrative Memory" test

The test is an old and familiar one, fully described by Whipple (9) who calls it "logical" memory. It was given by us as a group test. All subjects having been provided with paper, it was explained that a short story would be read to them. This story they were to remember and write down at once from memory. It was made clear that it would be read only once, that the exact words were perhaps advisable but not required and that, though ample time would be allowed, too much time should not be taken over the work. For the first story about five minutes were allowed for reproduction, although the experimenter used his judgment in allowing extensions to those of the younger subjects who were handicapped by slow penmanship. It was also explained that the story was Chinese, and the name of the principle character was written upon the board for them. The following story including the title was then read rather slowly to the pupils:

The Priest

"Tang, | when his | wife | died, | left home | and became a priest | of a particular order. | Some years afterwards | he returned | dressed in the garb | of his order | and carrying his praying mat | over his shoulder; | and after staying | one night | he wanted to go away again. | His friends however | would not give him back | his cassock | and staff; | so at length | he pretended | to take a stroll | outside the village, | and when there, | his clothes | and other belongings | came flying | out of the house | after him | and he got safely away." |

No. of "ideas," 31.

At the second test the following story was substituted for "The Priest."

The Spirits | of the Lake.

"An official | named Chung | was appointed | to a post | at Peking, | and on his way thither | crossed a lake. | Happening

to visit | the shrine | of the local spirits | he noticed an image | of a well known soldier | and another of a namesake of his own, | the latter occupying a very inferior position. | "Come! Come!" said Chung, | "my patron saint | shan't be put in the background | like that." | So he moved the image | into a more honourable place | and then | went | back | on board his boat again. | Soon after a great wind | struck the vessel | and carried away the mast | and sails; | at which the sailors | in great alarm | began to howl | and cry. | However, in a few moments | they saw a small skiff | come cutting through the waves | and before long | they were all | safely | on board.[17] | The man who rowed it | was strangely like | the image | in the shrine | the position of which Chung had changed. | He brought them to land safely | and then skiff | and man | both vanished." |

No. of "ideas," 46.

The stories used by Whipple (9), Henderson (4), Shaw (6) and others were rejected for several reasons. "The Marble Statue" is too well known, the paragraph on Cicero is rather abstruse and would certainly be more favorable to the boys at the Group A school who have studied classics, and "The Dutch Homestead" is too favorable to people with a good visual memory, whereas we were trying to test "logical" memory. The stories selected are simple, of a type not unfamiliar and yet with a flavor of novelty and almost certain not to have been previously read by any of the subjects. This test more nearly resembles school work than any other. In both schools, in fact, something very similar had been given as a class exercise, in neither case, however, at all frequently. It is possible though not likely that the overwhelming superiority of Group A is in part due to greater practice.

Marking this test is very difficult. The selections were divided into "ideas" or details as indicated above and subjects scored 1 for each idea reproduced. An appearance of having an objective standard is thus obtained. In application, however, one's personal judgment must play its part. What constitutes reproduction of an idea, how to grade a pupil with a charming concise style who gets the "meat" of a story with half the ideas reproduced by more verbose subjects—these are a few of the per-

[17] "They were all —— on board" is one idea, "safely" another.

plexities one meets. The writer corrected all the papers, going over them three times.

The reliability of the test is very high, the coefficients being, for Group A .587 ± .076, and for Group B, .556 ± .089. In both groups it correlates rather highly with "Imputed Intelligence." Of the other correlations one should perhaps notice in Group B the higher correlation of this test with all divisions of the "Alphabet test." None of the others seem to call for special comment here.

TABLE XII

"Narrative Memory"—Results in No. of units reproduced

First Testing

	Averages by Divisions						Highest possible score 31					
	I	II	III	IV	V	VI	Best	Worst	Median	Mean	s	E of M
Group A	12.16	17.83	19.0	21.16	22.0	25.16	27	8	20	19.6	4.43	±.492
Group B	9.8	10.8	12.8	15.6	17.0	19.4	20	9	14	17.8	5.40	±.654
Second Testing												
							Highest possible score 46					
Group A	19.3	23.3	28.3	31.5	32.83	36.0	37	14	30	28.59	6.26	±.695
Group B	10.2	15.6	17.8	19.6	23.2	27.4	28	6	18	18.94	5.98	±.727
Amalgamation												
							Highest possible score 38.15					
Group A	15.75	20.67	23.7	26.33	27.42	30.58	31.5	14.5	22.5	24.095	5.28	±.585
Group B	10.0	13.2	15.3	17.6	20.1	23.4	23.5	7.5	19.	18.37	5.20	±.630

As a reference to Fig. XII and Table XII will show, the superiority of Group A was almost overwhelming. The arbitrary abscissae chosen for the graphs rather obscure the fact that the top half of one curve merely reaches the bottom half of the other. When we observe, however, that the median of the one group is practically equal to the best attainment of the other, some measure of the superiority is gained. This is fairly evenly marked all along the line although, as is often the case, there is a tendency (here more pronounced than usual) for the poorest divisions to approach each other.

Less experience is required to give this than any other test and it is, therefore, more suitable for general application by teachers to large numbers of schools. After what was said above as to

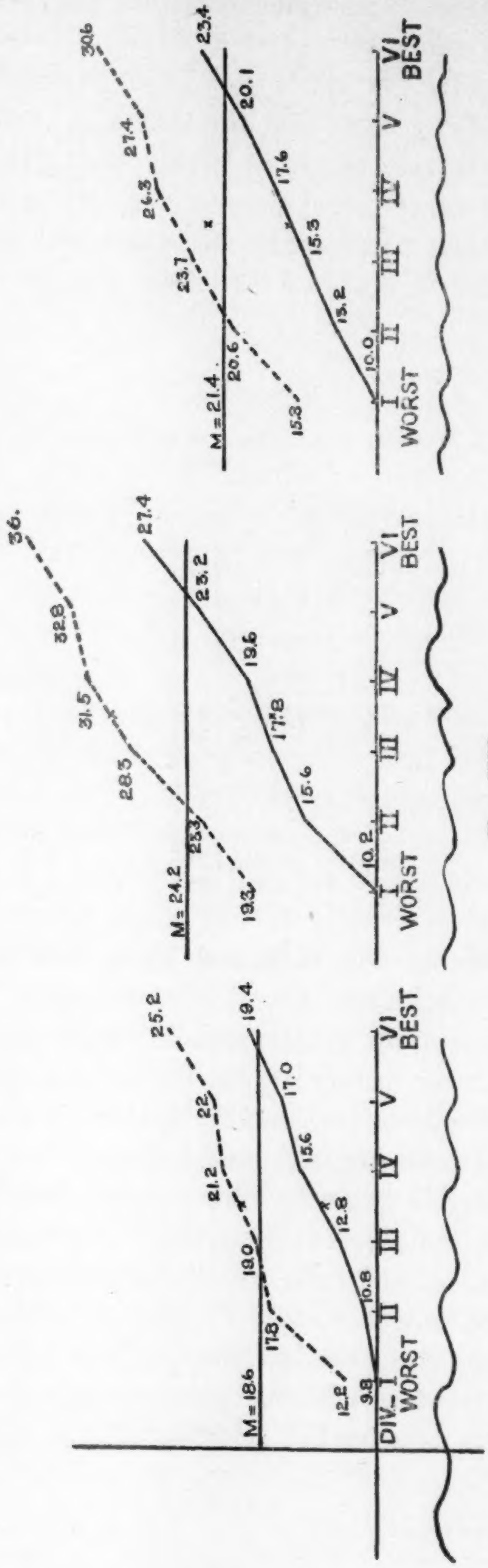


FIG. XII.

the difficulty of marking these papers, one need hardly point out that this should be done by *one person,* for the whole series of papers. To get more objective results, these might be separately marked by a second experimenter and the average taken. With these precautions, the test should be of very great and extended usefulness.

11. "Immediate Memory" or "Memory for Unrelated Words" test

The method is very like that of Meumann (3) as modified by Burt (2). The most convenient and simple form of apparatus is that devised by Miss Bickersteth. She fastened together three circular discs of mill-board in such a way that the inner disc could be rotated between the two outer discs. In these latter slots or windows were so cut as to show at a time only one of the words printed on the inner disc. By using both sides, each set of discs may be employed for two series of words. We actually used the same apparatus as Burt but are convinced that from the subject's view-point there is no difference between the two. The following five series of words were used, one of four words, three of six words each and one of eight words. One-syllable, common, concrete words were chosen but care was taken to secure that none had any very obvious connection with other words in the same or adjacent series.

First Testing

book	beg	cow	star	bell
mole	sun	sack	cork	kite
raid	joke	king	rice	sea
neck	rate	ride	man	mass
	meal	lake	pit	rut
	note	dog	lock	box
				maid
				gun

Second Testing

park	bat	snow	dell	chin
coat	tin	leg	pin	pig
shell	gate	cup	rose	desk
nail	rain	watch	frog	oar
	cut	pen	hut	nib
	fig	glove	cat	mass
				spoon
				fish

The instructions were as follows: "I am going to show you some short easy words through this slot. As they appear here you are to read them aloud. When you've read the last one, which will always have a line under it, you are to write them down here. And you must write them in the exact order in which they appear. Now I *don't* mean by that that you must write the first before you write the second and the third before the fourth. I mean that when you have finished, the first must stand here before the second. Write them *backwards* if you like, but then you must begin at the bottom. You see what I mean? Pay close attention while you read so that you can remember—and read them aloud! There will be four (six or eight) words this time. Ready?" As far as possible the words were presented to the subject so as to encourage him to read them in pairs with a marked rhythm but it must be confessed that none of the pupils took advantage of this to any marked degree. A few only of the better subjects in Group A read the words with a slight rhythm when repeating the test. Nevertheless in the preliminary test at St. Phillip's school, it was found that the series of 5 and of 7 were more difficult and hence only series of an even number of words were used. To urge subjects to read rhythmically only confuses them. A tablet with appropriately numbered spaces was provided for the writing.

It was felt that to score the same for words in a series of four and in a series of eight would be manifestly unfair. It is very easy to remember all the words in the shorter series, quite difficult to remember even the same number of words and get them into their proper places in an eight-word series. Accordingly it was decided to give 4 for each word in its proper position in the series of four, 6 for each word in the series of six, and 8 for each in the series of eight. For a displacement of one step in either direction, we deducted one point, of two steps, two points, and so on. A correct word moved from first to last place in any series thus counted one. If either the initial or final consonant or the medial vowel was incorrectly reproduced, the word was given half what it would score in that position. If more than one of these elements was wrong, the word was not considered reproduced at all. Fractional scores were not given.

The test is one of the most reliable used, the coefficients being .756 ± .050 and .508 ± .096 for Groups A and B respectively. The table of correlations shows few points of interest. One should perhaps note the high correlation with the "Spot Pattern" test in Group A and its failure to correlate with it in Group B. The explanation of this fact, however, lies rather in the fact that the "Spot Pattern" test exhibits different correlations in the two groups almost throughout. The higher correlation with "Analogies" and the very much higher correlation with "Imputed Intelligence" in Group A, leads one to judge that the test correlates with intelligence rather more highly in this group than in Group B. If we postulate (as the writer is strongly inclined to do) that the central factor in intelligence is adaptability, this becomes explicable. For it is quite certain that the instructions are too full to be easily grasped. In Group B fully 80% of the subjects had to be reminded that they were to read the words aloud. And it was quite clear that failure to grasp the idea of the test was so general that the whole factor of adaptability was somewhat obscured except where it was strongest.[18] The same considerations apply, it is true, to Group A, but to a very much smaller extent. To anticipate somewhat our general conclusion, the proportion of specially intelligent children is there undoubtedly (if our tests mean anything at all) very much greater. Hence the number of those whose power of adaptation would rise above the rather high threshold which the conditions of the test impose upon it, would be greater. And the more this plasticity comes into operation the higher the correlation with intelligence. Whether or not this somewhat speculative conclusion be valid, it is certain from our experience that the test would be improved if the instructions could be somewhat simplified. But the only way which we can suggest for this is a trial series of four.

Turning now to the actual results, we find once more a decisive and unequivocal superiority in Group A. A glance at Fig. XIII and Table XIII shows this quite plainly.

[18] The adaptability of one subject in Group A showed itself in an embarrassing manner. He adopted the plan of not reading the new word until he had run over the *previous* members of the series. Of course the scheme, however ingenious, could not be countenanced.

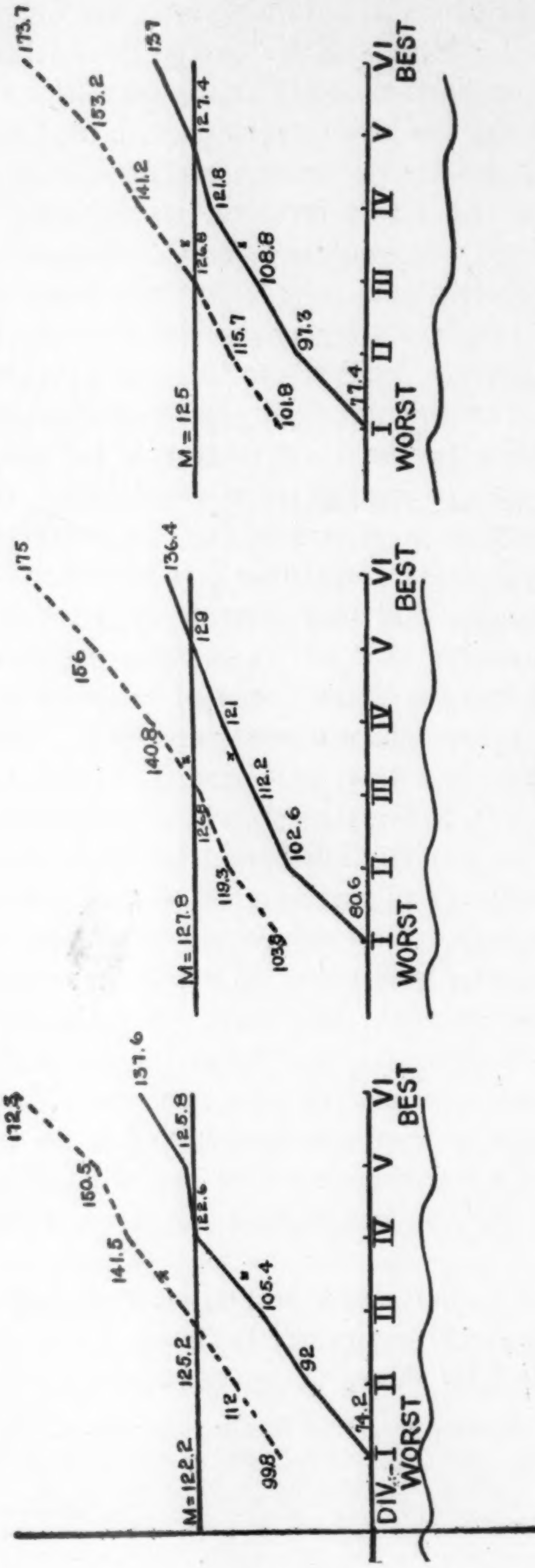


FIG. XIII

TABLE XIII

"Immediate Memory"—Results in units scored; possible score, 188.

First Testing

	Averages by Divisions						Best	Worst	Median	Mean	s	E of M
	I	II	III	IV	V	VI						
Group A	99.8	112.0	125.2	141.5	150.5	172.3	188	97	133	133.81	36.68	±4.07
Group B	74.2	92.0	105.4	122.6	125.8	137.6	147	65	110	108.29	23.7	±2.87
Second Testing												
Group A	103.8	119.3	126.8	140.8	156.0	175.0	186	88	131	139.51	26.0	±2.89
Group B	80.6	102.6	112.2	121.0	129.0	136.4	141	63	118	113.77	18.99	±2.4
Amalgamation												
Group A	101.8	115.7	126.8	141.2	153.2	173.7	180.0	99.0	128.0	136.66	26.38	±2.93
Group B	77.4	97.3	108.8	121.8	127.4	137.0	137.5	64.5	112.5	111.03	21.83	±2.64

Additional evidence as to the value of this test is not needed, since it is perhaps the most extensively used single test. Our experience leads us to confirm Burt's view that simplicity and absence of distraction are more valuable than a perfectly regulated tempo. Miss Bickersteth is applying this as a group test. It will be interesting to compare her results with those obtained from Group B—her work being in comparable schools.

12, 13, 14. "Discs and Circles" tests

12 = "Disc Sorting;
13 = "Circle Judging";
14 = "Discs and Circles Combined."

The test is an entirely new one, designed to test three qualities: disc sorting for motor dexterity (a phase of discrimination reaction-time) and perceptual discrimination; circle judging for quickness and accuracy of discrimination—judgment; and both in combination for the ability to divide attention as well. This test was applied only to the boys of the Central school (Group B).

A reading desk or lectern was constructed by attaching to a substantial wooden base an upright, 28 cm. in height, and sufficiently broad and thick not to vibrate, which supported a rest at a convenient angle for reading (about 35 degrees from the perpendicular). The rest was provided with a small cleat at the bottom to keep the cards from slipping. In the same base just in front of the inclined lectern were set vertically, from left to right, three brass rods about 1 cm. in diameter, 30 cm. high, and 19 cm. apart. The tops of these rods were slightly rounded.

Thirty wooden discs were made, 15 white and 15 very dark brown, 5.5 cm. in diameter, 8 cm. thick and provided with a hole in the center about 1.3 cm. in diameter, so as to slip easily over the rods. The edges were milled and slightly beveled to facilitate grasping.

A small demonstration card had drawn upon it 12 pairs of circles ar-

ranged in 3 columns. In each pair, the circles (which were lettered) differed very materially in size. Three other cards had each thirty pairs of circles arranged in four columns. The circles here varied in diameter from 2.45—1.6 cm., but the difference in any one pair was never so great. The size-differences were of three grades of difficulty, with ten pairs for each grade. Unfortunately in the confusion involved in the commandeering of the Oxford Laboratory by the British War Office, these cards were lost and it is now impossible to say exactly what the differences were. They ranged from 1 mm. to 2 or 2.5 mm. The various size-differences were distributed in random order through the four columns of a card. As on the demonstration card, the circles were lettered. Only consonants were used and in each pair, consonants of distinctly different sounds—as X and T, or M and V.

The subject was seated before the apparatus on a rather high seat. The discs were put on the middle rod in the following order from bottom up: 1 white, 1 black, 2 white, 1 black, 1 white, 2 black and repeat. The order was kept the same for all, yet was sufficiently complicated to appear quite a random order to the subjects.

For "Disc Sorting," the subject was required to separate the discs, putting the white on the rod to the right, the black on the rod to the left, using only his right hand, taking the discs one at a time, and keeping his eye all the time on a fixation point in the middle of the lectern. Time was taken in fifths of a second.

For "Circle Judging," the subject was given a practice test on the demonstration card and the task carefully explained. He was to call the letter in the larger circle of each pair, taking each pair in order right down the column. Emphasis was laid as nearly as possible equally on correctness and speed. Time was taken as usual and the number of errors was noted. Different errors must be given different penalties since the difficulty of judgment is not equal.

For the combined test the subject was required to do both tasks simultaneously. It was made clear that the dropping of the disc need not be simultaneous with the giving of a judgment but the great majority of the subjects adopted this procedure—"from not being able to do anything else," they explained. The result was that the time of the combined tasks was that of the subject's slower task slightly increased. However, in a few cases there was a measureable difference between the times for the two tasks. Hence in all cases, the two tasks were separately timed, using a split-hand stop-watch. (One operation starts the two hands together but they can be separately stopped.)

The reliability for "Disc Sorting" is good ($r = .481 \pm .100$). The correlation with the headmaster's estimate of intelligence is about the same as that for "Dotting," $.262 \pm .120$. Other correlations may be found in the table. As might be expected, the correlation with "Dotting" is rather high but that with "Tapping" is unexpectedly low. None of the other correlations present unusual features except, perhaps, the divergence between the indices for "Narrative Memory" on the one hand, and that for "Related Memory" on the other. The best performance was 51.7", the worst 67.9", the median 57.4".

The reliability is again high for "Circle Judging" (r = .565 ± .088) and the correlation with the headmaster's estimate is much greater (r = .315 ± .116). The best performance was 33 2/5", the worst 62 3/5", the median 52".

For the combined test, the subjects were ranked in order according to their performance in each of the two tasks and the two ranks then amalgamated. The reliability of such an amalgamated rank is always slightly higher than would appear from Spearman's "reliability coefficient," which in this case is already high (r = .565 ± .088. The correlation with "Imputed Intelligence" is not very great, but appreciable. The best performance was 70" for the discs, 51 2/5" for the circles, the poorest was 94" and 106 4/5", and the median was 73 4/5" and 76 1/5".

The test requires considerable practice for successful application and takes more than a quarter of an hour for each subject. This is probably more than the test as a whole is worth. The writer feels that only the judging of circles should be retained as a test of intelligence.

A possible improvement would be to put the pairs of circles on separate cards to be dealt out to the subject at a definite, regulated speed. Excellence would then be determined solely upon the number of errors, not upon a union of time and errors. Children, however, unless the time allowed for each judgment is long, are apt to get rattled and go all to pieces, calling out one or the other of the circles quite at random. If the time allowed is too long, the abler subjects can do the test too easily. Only by experiment could one tell whether or not the proposed change would work.

VII. General Conclusions

A. *The Usefulness of the Several Tests.* The "Alphabet" tests ("Letters," "Figures" and "Alternating"), "Analogies," and the three "Memory" tests, with perhaps the "Circle Judging" test are alone recommended for general purposes, and these should be modified in the manner described under their several headings. "Tapping," "Dotting," and "Disc Sorting" may be useful tests under more special conditions, though their correlation with "Intelligence" is probably negative or so low as to be somewhat doubtful. We found all of the tests more or less useful for our more specific purpose of comparing two groups of boys—each group homogeneous—of widely different inheritance.

Our testing was not, of course, as complete and adequate as one could wish, but even so, the time consumed for the ten tests was about one hour for each subject—for tests individually given —and half an hour more for the two group tests. The "Disc" and "Circle" tests increased the time by about twenty minutes

for each subject. We should have liked to test other functions, to test each function in two different ways, etc. But this time element, for both experimenters and subjects, is an inevitable bugbear in mental testing and one must draw what conclusions one can from what data the exigencies of the particular situation allow one to obtain.

Relatively speaking, then, memory (three tests) and perceptual discrimination ("Alphabet" tests and "Dotting" test) are here pretty thoroughly tested, and analogical reasoning ("Analogies") satisfactorily tested. So, too, with the function or group of functions enabling one to sustain a very rapid movement of the arm not requiring great accuracy ("Tapping"), and with the function or group of functions controlling accurate, quick movement ("Dotting"). Less satisfactorily and less directly we have tested attention (practically all tests but especially "Dotting," "Spot Pattern" and "Alphabet" tests) and the distributing of attention ("Alternating") and the ability to comprehend spacial relations or rather to introduce order into one's spacial perception ("Spot Pattern"). In the "Related Memory" and "Narrative Memory" tests, we have also an indirect measurement of the ability to grasp conceptual relationships of the simpler sort.

B. *Comparison of the Two Groups.*—One may first consider the extent of the superiority—already commented on—of Group A and then the distribution of the superiority within the groups. The material for the comparison lies in the tables and diagrams accompanying the respective tests and there discussed somewhat briefly. In many respects, the curves show most clearly and fairly how great is the superiority. Table XIV, however, enables one to compare the results with those of other experimenters. The percentage of each group falling below the amalgamated mean for all subjects, both groups, was calculated. As practice effects enter in, we take the two trials of the various tests separately.

It will be observed that about two-thirds of Group A and about one-third of Group B are above the mean. Since the "Tapping" test shows either no correlation with "Intelligence" or a negative one, it would be better to remove it from the list. We

TABLE XIV

Percentage of Subjects Falling Below the Mean

First Testing

	2. Letters	3. Figures	4. Alternating	5. Tapping	6. Analogies	7. Dotting	8. Spot Pattern	9. Related Memory	10. Narrative Memory	11. Immediate Memory	Averages
Amalgamated Mean of Two Groups	124.1	101.3	328.1	287.9	4.57	121.2	26.0	11.6	18.6	122.2	
% of Group A falling below this Mean	21.62	32.43	18.91	62.16	10.81	57.75	38.84	18.91	32.43	35.13	32.8
% of Group B falling below this Mean	54.84	58.06	58.06	38.71	48.39	61.29	67.74	74.20	83.88	70.97	61.61
Second Testing											
Amalgamated Mean of Two Groups	113.5	98.2	289.3	281.5	6.12	132.3	26.4	15.4	24.2	127.8	
% of Group A falling below Mean	37.84	35.13	16.21	56.75	24.32	45.94	45.94	18.91	27.03	40.54	34.86
% of Group B falling below Mean	54.84	70.97	67.74	32.26	64.52	58.06	61.29	70.97	74.20	70.97	62.58
Average of Two Testings											
Amalgamated Mean of Two Groups	118.8	99.8	308.7	284.8	5.34	126.8	26.2	13.5	21.4	125.0	
% of Group A falling below Mean	29.73	33.78	17.56	59.43	17.56	51.34	41.89	18.91	29.73	37.84	33.83
% of Group B falling below Mean	54.84	64.52	62.9	35.48	56.46	59.68	64.52	72.58	79.04	70.97	62.1

TABLE XV

First Testing

Percentage of Group B Surpassing	2. Letters	3. Figures	4. Alternating	5. Tapping	6. Analogies	7. Dotting	8. Spot Pattern	9. Related Memory	10. Narrative Memory	11. Immediate Memory	Average	Average Without Tapping
All but 1, or 96.2% of Group A	0.	0.	0.	9.68	3.23	6.45	0.	0.	0.	0.	1.94	1.07
All but 4, or 89.2% of Group A	9.68	0.	0.	22.58	3.23	9.68	3.23	0.	0.	0.	4.84	2.87
All but 9, or 75.7% of Group A	9.68	3.23	0.	41.94	6.45	29.03	16.13	0.	0.	3.23	10.97	7.53
50% of Group A	22.58	9.68	3.23	70.97	6.45	45.16	19.35	3.23	0.	9.68	19.03	13.29
Lowest 9, or 24.3% of Group A	38.71	61.29	38.71	90.33	29.03	64.52	64.52	3.23	16.13	41.94	44.84	39.79
Lowest 4, or 10.8% of Group A	67.74	74.20	64.52	100.	74.20	77.42	74.20	41.94	38.71	67.74	68.07	64.52
Lowest 2, or 5.4% of Group A	77.42	87.10	93.55	100.	96.78	87.10	90.33	71.	100.	70.97	87.42	86.02
Lowest 1, or 2.7% of Group A	77.42	87.10	96.78	100.	96.78	93.55	96.78	83.9	100.	70.97	89.33	88.14
Second Testing												
All but 1, or 96.2% of Group A	0.	3.23	0.	6.45	3.23	9.68	0.	0.	0.	0.	2.26	1.78
All but 4, or 89.2% of Group A	0.	6.45	0.	16.13	3.23	12.90	3.23	0.	0.	0.	4.19	2.87
All but 9, or 75.7% of Group A	9.68	9.68	0.	48.39	3.23	29.03	12.90	0.	0.	0.	10.59	6.17
50% of Group A	19.35	19.35	22.58	80.65	19.35	35.48	32.26	3.23	0.	12.90	24.52	18.28
Lowest 9, or 24.3% of Group A	64.52	35.48	32.26	96.78	41.94	77.42	51.61	25.81	25.81	48.39	50.	47.03
Lowest 4, or 10.8% of Group A	74.20	45.16	64.52	100.	64.52	83.88	77.42	45.16	32.26	64.52	65.16	61.28
Lowest 2, or 5.4% of Group A	87.10	64.52	74.20	100.	77.42	96.78	80.65	48.39	41.94	79.42	74.84	72.05
Lowest 1, or 2.7% of Group A	93.55	70.97	80.65	100.	83.88	96.78	100.	90.33	83.88	87.10	88.71	87.36

TABLE XV Continued

Average of Two Testings

Percentage of Group B Surpassing	2. Letters	3. Figures	4. Alternating	5. Tapping	6. Analogies	7. Dotting	8. Spot Pattern	9. Related Memory	10. Narrative Memory	11. Immediate Memory	Average	Average Without Tapping
All but 1, or 96.2% of Group A	0.	1.62	0.	8.06	3.23	8.06	0.	0.	0.	0.	2.10	1.43
All but 4, or 89.2% of Group A	4.84	3.23	0.	19.36	3.23	11.29	3.23	0.	0.	0.	4.52	2.87
All but 9, or 75.7% of Group A	9.68	6.46	0.	45.16	4.84	29.03	14.52	0.	0.	1.62	10.78	6.85
50% of Group A	20.96	14.52	12.90	75.81	12.90	40.32	25.80	3.23	0.	11.29	21.78	15.78
Lowest 9, or 24.3% of Group A	51.62	48.38	35.48	93.56	35.48	70.97	58.06	14.52	20.97	45.16	47.42	43.41
Lowest 4, or 10.8% of Group A	70.97	59.68	64.52	100.	69.36	80.65	75.81	23.55	35.48	66.13	66.62	62.90
Lowest 2, or 5.4% of Group A	82.26	75.81	83.88	100.	87.10	91.94	85.49	59.68	70.97	74.20	81.13	79.04
Lowest 1, or 2.7% of Group A	85.48	79.04	88.72	100.	90.33	95.16	98.39	87.10	91.94	79.04	89.02	87.75

then find the proportion even more in favor of Group A. An average of but 30.95% of the group falls below the mean while in the rival group an average of 65.0% falls below, or more than twice as many. The extent to which the two groups overlap may also be judged from Table XV showing the percentage of those in Group B surpassing certain given percents. of Group A.

These figures show, then, a quite unambiguous superiority in the boys drawn from the better social class. Let us inquire a little more in detail into the distribution of this superiority among the members of the respective groups. Both groups show a few individuals who are very stupid relative to the other members of their group. They are sharply marked off even from those subjects just next above them. The number of these very poor subjects varies, of course, from test to test, but is usually from two to four. If stupidity be measured by the attainment of the stupid members of the better group, we have two to four stupid subjects in that group and seven to twelve in the other—from three to four times as large a proportion. If, on the other hand, stupidity be measured by the attainments of the stupid members of the poorer group, we have four stupid subjects there and but one in the better group.

The next seven boys in Group A are what one must call rather dull. Eleven pupils in the other school have similar attainments —about twice as many in proportion. Less than half the boys in Group B rise *above* the attainment of the "dull" members of the other group. The next nineteen boys in Group A represent the average for that group, constituting a little over half of the total number. Even this average attainment was too much for the other group, only 37% doing as well.

The superiority is still more marked when we come to the "bright" class. As compared with 22% in the A school, only 6% in the B school reach this standard. Finally, in only two tests out of nine ("Tapping" being omitted in all of the above, since it does not correlate with "Intelligence") the best subject was from Group B, in seven from Group A. In the "Dotting" test, the second best subject was in Group B, in all the others he was in Group A.

The following distribution curve presents these facts in graphic form.[19]

The difference between the two groups is marked at every point. The proportion in the one group of very inferior and in-

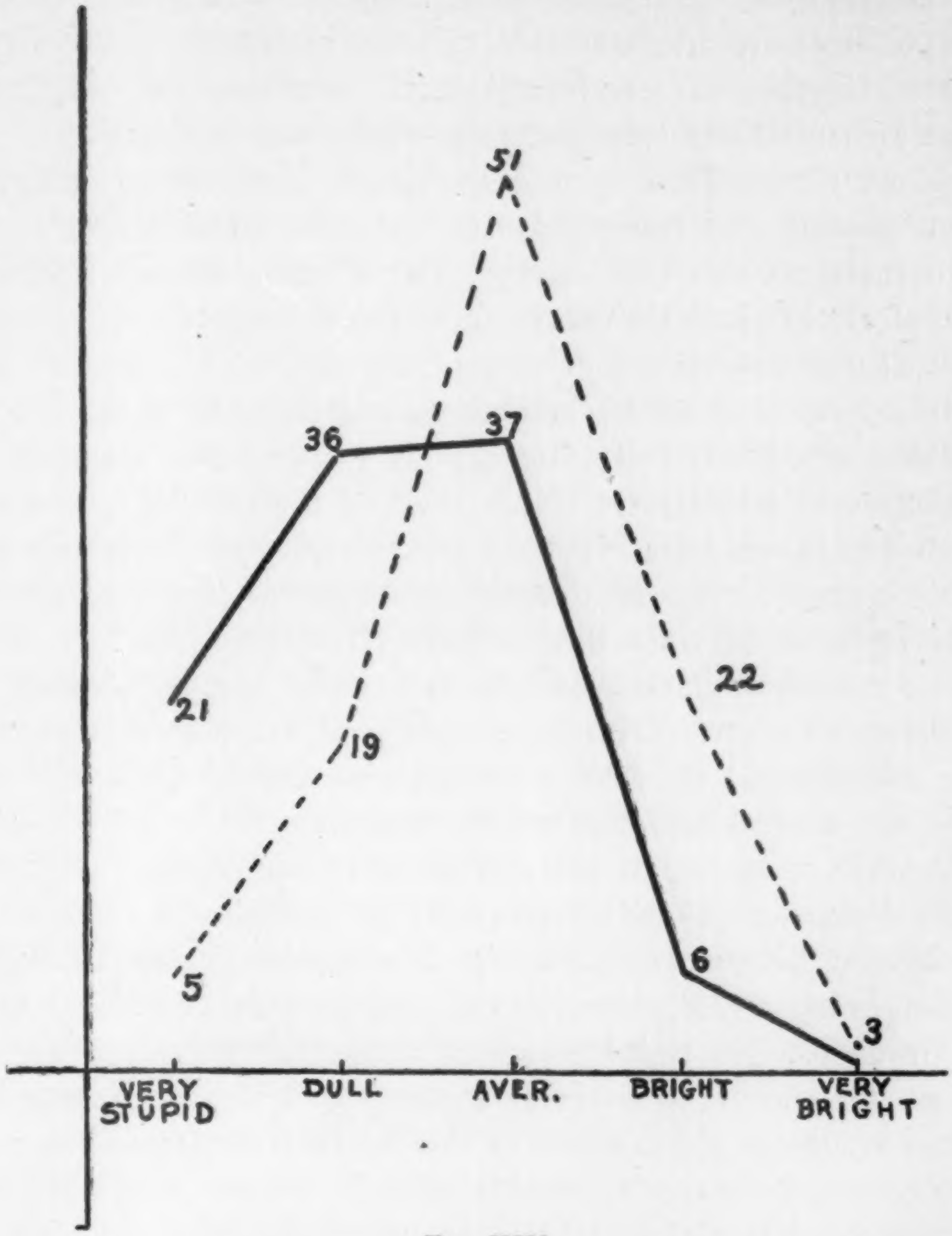


FIG. XIV

[19] The division into stupid, dull, average, bright and very bright is, of course, largely arbitrary. The writer merely classed the Group A boys according to their attainments in the tests roughly into those categories and placed in any given category those members of the other group having similar attainments. Thus whatever be the validity of the terms applied, the comparison is fair.

ferior subjects is so large that not even the number of average or mediocre subjects compares favorably with that of the other group. In the "bright" and "very bright" categories, the comparison is a little more favorable. For although but two subjects reach this category in Group B as compared with nine in Group A, yet these two do pretty well, since they rank fourth and sixth for all tests together, and all subjects. Yet here, too, it is clear that the superiority is unqualifiedly on the side of Group A.

Now, although the groups are small, they are exceedingly homogeneous and thoroughly representative of the children in two social or economic strata. The writer does not hesitate, therefore, to predicate these results for the children of the entire classes represented, or to conclude that the children of the professional class exhibit between 12 and 14 years of age a very marked superiority in intelligence—in so far as our results give a picture of intelligence. How much of the superiority are we justified in ascribing to heredity and how much to environment? This is quite a different question from that of *untrained* versus *trained* functions. Speaking broadly, all of these tests levy upon functions which have been exercised. But specific training is a different matter. With the exception of "Narrative Memory" the subjects had no specific training for any of the tests. In that test, all had had some specific training.

At the very outset we are confronted by one striking and constant difference (already mentioned) in the attitudes of the two groups—a difference in alertness. The boys in Group A seemed somehow more vital, more vibrantly, exuberantly alive than those of Group B. This trait shows itself in the tests in various forms: in greater energy, in a keener sense of competition, perhaps in better attention, and in a greater intellectual curiosity. Certainly this general alertness (or its absence) affected the quality of performance. I speak now of groups, not of individuals, for there were conspicuous exceptions in Group B, less conspicuous exceptions in Group A. How much of this, then, may we attribute to environment? None at all to the influence of the teachers, for the whole attitude of the teachers of Group B was far less repressive, less rigorously disciplinarian than of the

Group A teachers. It is probably true that discipline was less in evidence in the one school than in the other largely because less needed—and this, perhaps, because of the natively greater "docility" of the Group B pupils.

A certain amount of the difference between the groups is no doubt due to home influences. Almost as important is the influence of fellow pupils. In an atmosphere of mental alertness, the duller boys are stimulated to more than their normal energy. That the majority of the Group A boys were more alert is, in the writer's opinion, responsible for the fact that there were *no* cases in this group of the dull, passive type. It does not follow, however, that in an inert group, native alertness is stifled. On the contrary, it is developed. Leadership, with its responsibility, is very valuable and naturally falls to the lot of wide-awake members of the group. And it is to this we attribute the fact that a few of the boys of Group B are as quick and as energetic as all save the best boys of Group A, although the majority are, as above stated, somehow less "vital." This trait, then, of alertness may be due in part to environment. Yet that cannot be the sole explanation. Some part, in the author's opinion, a very large part, is due to heredity—certain features in the environment of both schools simply helping to develop the trait if one has it inborn. The influence of this characteristic is, in any case, very variable both with tests and with individuals. Generally, it is a help to its possessor, but, so far as one can see, not the chief determining factor. It is clear, at any rate, that the influence of environment upon the tests *via* "alertness" is small. Alertness, itself largely innate, is only one of many determining factors.

Again, if ability in these tests be due in large part to education and training, how are we to account for the very large individual differences within the two groups—differences greater than between the groups? For within these groups education has been almost exactly the same and even the home training has certainly been marked by great uniformity.

Unless, however, one has himself carried out the series of tests, the above observations may seem very speculative. We

may perhaps adduce a few more concrete bits of evidence. In groups as homogeneous as ours, age may be taken as a direct means of estimating the extent of the influence of environmental factors. It will be observed that the correlations of the several tests with age are very small, generally negligible, *especially in Group A where environment has been the better.* The smallness of the correlation of age and the several tests is a direct proof that environment and the tests have also a low correlation.

One may also refer to some results obtained by Mr. Cyril Burt (2). Working with tests, at least generally comparable with those above described, Burt found that after 18 months the same subjects showed either no marked improvement or an actual deterioration, most of the capacities remaining stationary. "Yet the boy's mental equipment has not. A somewhat 'dull' boy, for instance, who was 25th [out of 30] in the amalgamated list for Six Tests in 1908, has in 1909 risen to a place in the school occupied in 1908 by a 'clever' boy, who was then 4th on the amalgamated list; yet his new measurements instead of concomitantly rising to equal those of the 'clever' boy are now equivalent to those of the boy who was [then] 24th. Similarly with most of the boys. Thus, though the period between the ages of 13 and 15 is for boys one of rapid progress in knowledge, interests and acquired aptitudes, yet in the capacities measured by the tests no corresponding alteration is made. Hence, these capacities appear to constitute a relatively permanent endowment; and consequently it seems legitimate to assume that they depend upon innate differences in the individuals concerned" (pp. 175-176).

To this conclusion, the present writer subscribes. Although he is not prepared to say and does not in fact believe, that environment has had nothing to do with the superiority of one group over the other, he is convinced that *the hereditary factor plays an altogether preponderating part.*

REFERENCES

1. Brown, Wm. *The Essentials of Mental Measurement.* Cambridge University Press, 1911.
2. Burt, Cyril. Experimental tests of general intelligence. *Brit. J. of Psychol.,* 1910, 3, 94-177.

3. Ebert, E., and Meumann, E. Ueber einige Grundfragen der Psychologie der Uebungsphänomene im Bereiche des Gedächtnisses. *Arch. f. d. ges. Psychol.*, 1905, **4**, 1-232.
4. Henderson, E. N. A Study of Memory for Connected Trains of Thought. *Psychol. Monog.*, 1903, **5**, No. 6, pp. IV + 94.
5. Pearson, Karl. On further methods of determining correlation. *Drapers' Company Research Memoirs, Biometric Series* IV, 1907.
6. Shaw, J. C. A test of memory in school children. *Pedagogical Seminary*, 1896, **4**, 61-78.
7. Simpson, B. R. Correlations of mental ability. Teachers College, *Columbia University Contributions to Education*, No. 53, 1912.
8. Spearman, C. Demonstration of formulae for true measurement of correlation. *Amer. J. of Psychol.*, 1907, 18, 161-169.
9. Whipple, G. M. *Manual of Mental and Physical Tests.* Baltimore, Warwick & York, 1910.
10. Wyatt, Stanley. The quantitative investigation of higher mental processes. *Brit. J. of Psychol.*, 1913, **6**, pp. 116 ff.
11. Yerkes, R. M., Bridges, J. M., and Hardwick, R. S. *A Point Scale for Measuring Mental Ability.* Baltimore, Warwick & York, 1915.

Table XVI
Table of Correlations

		2. Letters	3. Figures	4. Alternating	5. Tapping	6. Analogies	7. Dotting	8. Spot Pattern	9. Related Memory	10. Narrative Memory	Memory
2. Letters	Group A		47±09	74±05	02±12	26±11	06±12	33±10	46±09	26±11	31
	Group B		72±06	75±06	02±13	38±11	43±10	24±12	43±10	59±08	53
3. Figures	Group A	47±09		45±09	—11±12	07±12	—11±12	21±11	36±10	24±11	3
	Group B	72±06		81±04	—16±13	07±13	29±12	14±13	32±12	62±08	57
4. Alternating	Group A	74±05	45±09		—11±12	35±10	—01±12	42±10	47±09	33±10	5
	Group B	75±06	81±05		03±13	37±11	25±12	17±12	36±11	64±08	61
5. Tapping	Group A	02±12	—11±12	—11±12		—52±08	58±08	—24±11	—24±11	—40±10	—5
	Group B	02±13	—16±13	03±13		—10±13	22±12	19±12	001	—27±12	1
6. Analogies	Group A	26±11	07±12	35±10	—52±08		—52±08	28±11	53±08	51±09	6
	Group B	38±11	07±13	37±11	—10±13		08±13	35±11	26±12	56±09	2
7. Dotting	Group A	06±12	—11±12	—01±12	58±08	—52±08		05±12	—04±12	—21±11	—4
	Group B	43±10	29±12	25±12	22±12	08±13		02±13	37±11	10±13	0
8. Spot Pattern	Group A	33±10	21±11	42±10	—24±11	28±11	05±12		30±11	50±09	5
	Group B	24±12	14±13	17±12	19±12	35±11	02±13		15±13	32±12	0
9. Related Memory	Group A	46±09	36±10	47±09	—24±11	53±08	—04±12	30±11		43±10	4
	Group B	43±10	32±12	36±11	001	26±12	37±11	15±13		37±11	4
10. Narrative Memory	Group A	26±11	24±11	33±10	—40±10	51±09	—21±11	50±09	43±10		5
	Group B	59±08	62±08	64±08	—27±12	56±09	10±13	32±12	37±11		4
11. Immediate Memory	Group A	31±11	30±11	50±09	—57±08	66±07	—47±09	50±09	41±10	50±09	
	Group B	53±09	57±09	61±08	16±13	29±12	04±13	06±13	48±10	41±11	
12. Disc Sorting	Group A										
	Group B	18±12	18±12	18±12	12±13	24±12	54±09	40±10	33±12	05±13	1
13. Circle Judging	Group A										
	Group B	52±09	54±09	53±09	26±12	27±12	51±09	32±12	18±12	16±12	3
14. Discs & Circles	Group A										
	Group B	31±12	40±11	41±11	06±13	15±13	35±11	39±11	—05±13	13±13	3
15. Age	Group A	13±12	24±11	13±12	10±12	01±12	13±12	18±11	06±12	08±12	3
	Group B	47±10	33±12	29±12	25±12	02±13	28±12	05±13	30±12	14±13	2
16. Amalgamated Tests	Group A	73±05	57±08	80±04	—01±12	55±08	08±12	50±09	71±06	58±08	6
	Group B	87±03	69±07	82±04	15±13	55±09	45±10	45±10	62±07	71±06	6
17. Imputed Intelligence	Group A	25±11	32±10	58±08	—39±10	41±10	—23±11	38±10	31±11	56±08	7
	Group B	28±12	003	30±12	03±13	68±07	22±12	12±13	17±12	45±10	4
Test No.		2	3	4	5	6	7	8	9	10	

10. Narrative	11. Immediate Memory	12. Disc Sorting	13. Circle Judging	14. Discs & Circles	15. Age	16. Amalgted. Tests	17. Imputed Intelligence	Test No.
±11	31±11				13±12	73±05	25±11	2.
±08	53±09	18±12	52±09	31±12	47±10	87±03	28±12	
±11	30±11				24±11	57±08	32±10	3.
±08	57±09	18±12	54±09	40±11	33±12	69±07	003	
±10	50±09				13±12	80±04	58±08	4.
±08	61±08	18±12	53±09	41±11	29±12	82±04	30±12	
±10	—57±08				10±12	—01±12	—39±10	5.
±12	16±13	12±13	26±12	06±13	25±12	15±13	03±13	
±09	66±07				01±12	55±09	41±10	6.
±09	29±12	24±12	27±12	15±13	02±13	55±09	68±07	
±11	—47±09				13±12	08±12	—23±11	7.
±13	04±13	54±09	51±09	35±11	28±12	45±10	22±12	
±09	50±09				18±11	50±09	38±10	8.
±12	06±13	40±10	32±12	39±11	05±13	45±10	12±13	
±10	41±10				06±12	71±06	31±11	9.
±11	48±10	33±12	18±12	—05±13	30±12	62±07	17±12	
	50±09				08±12	58±08	56±08	10.
	41±11	05±13	16±12	13±11	14±13	71±06	45±10	
±09					32±11	62±07	73±06	11.
±11		11±13	32±12	32±12	24±12	66±07	49±10	
								12.
±13	11±13		21±12	23±12	10±13		26±12	
								13.
±12	32±12	21±12		72±06	35±11		32±12	
								14.
±13	32±12	23±12	72±06		38±11		22±12	
±12	32±11					31±11	40±10	15.
±13	24±12	10±13	35±11	38±11		33±12	000	
±08	62±07				31±11		61±07	16.
±06	66±07				33±12		45±10	
±08	73±06				40±10	61±07		17.
±10	49±10	26±12	32±12	22±12	000	45±10		
10	11	12	13	14	15	16	17	